

January 1997

Mobile Radio Technology[®]

Technical information for paging, SMR and private wireless networks.

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- Coaxial cable
- Open architecture networks
- Propagation analysis
- Product/Services showcase

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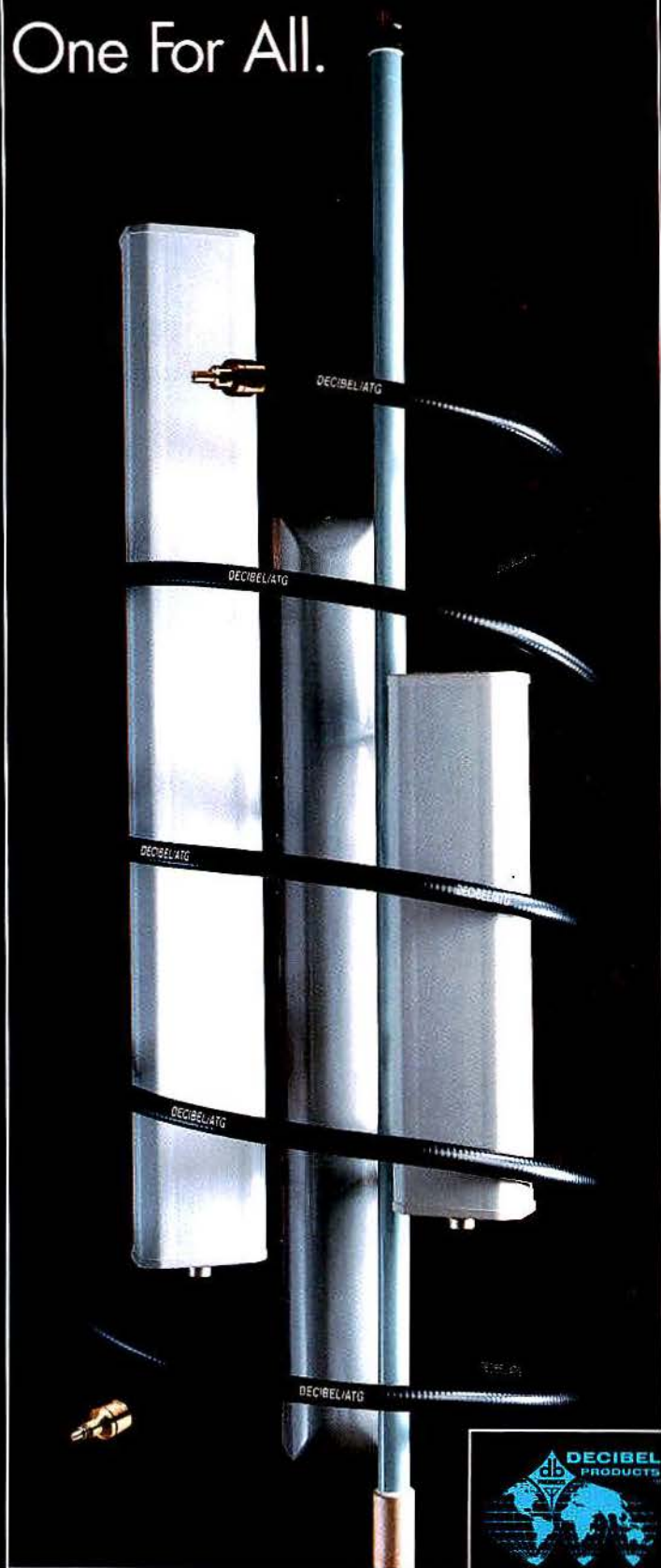
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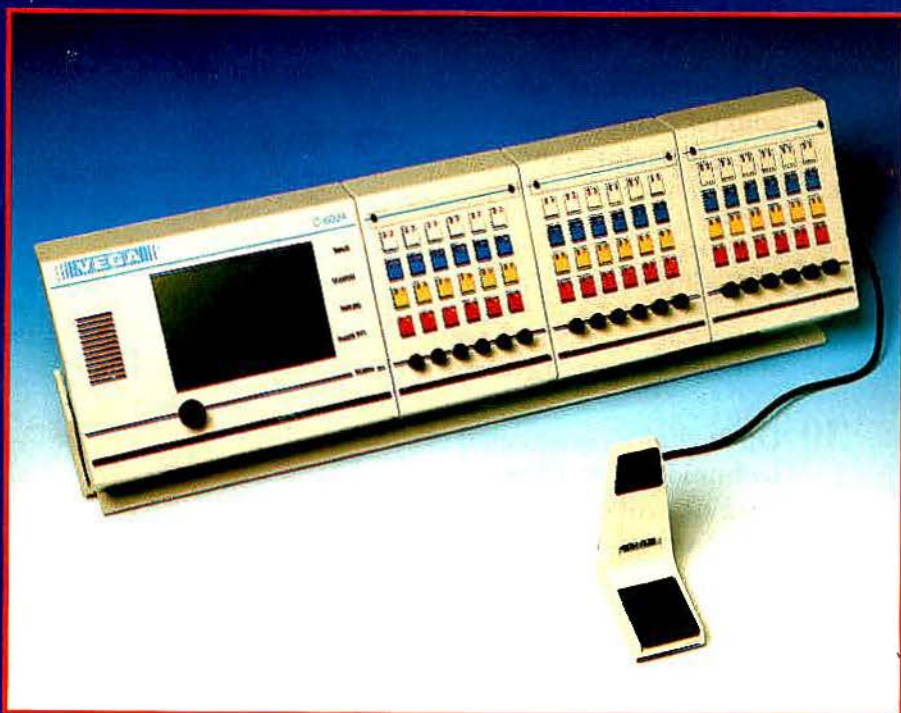
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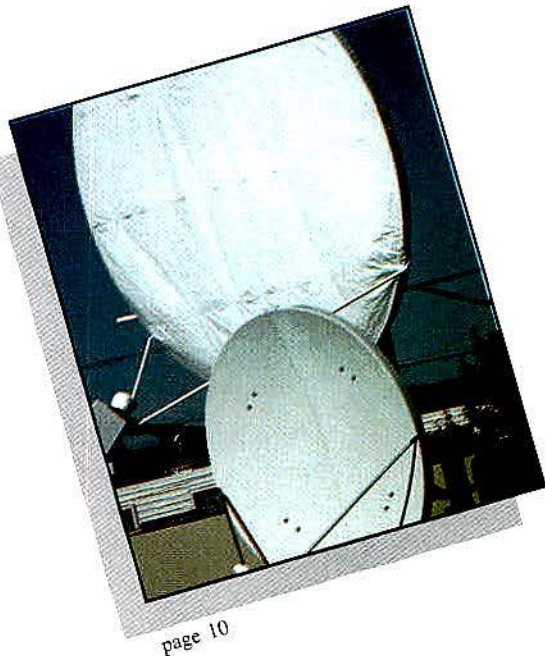
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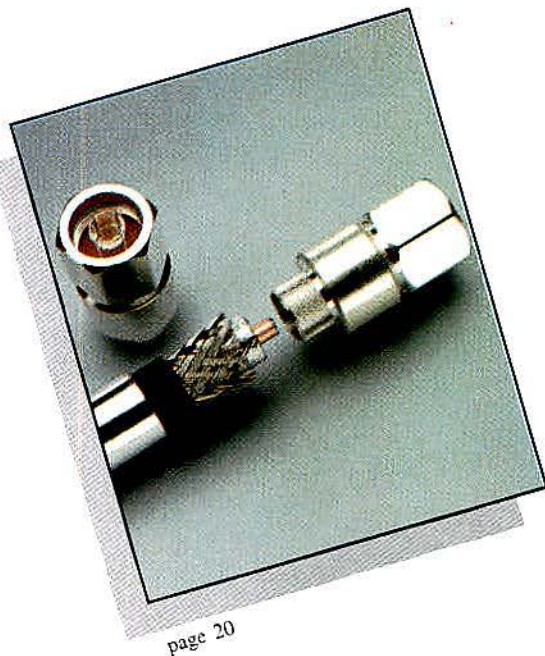
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SUBSCRIPTIONS: Non-qualified persons may subscribe at the following rates: United States and Canada: one-year: \$30.00. Qualified and non-qualified persons in all other countries: one-year: \$40.00 (surface mail); \$105.00 (air mail). Subscription information: P.O. Box 12937, Overland Park, KS, 66282-2937.

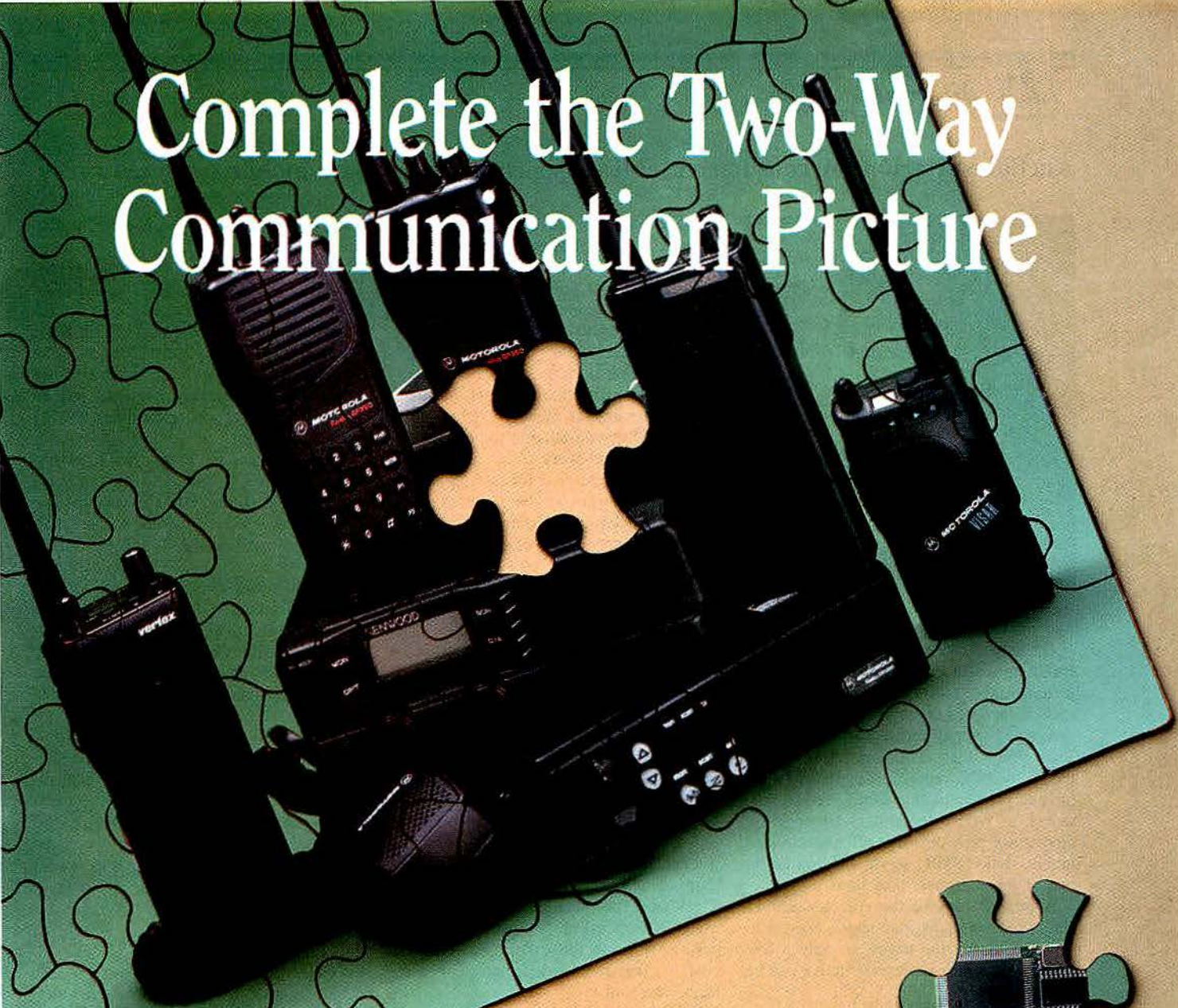


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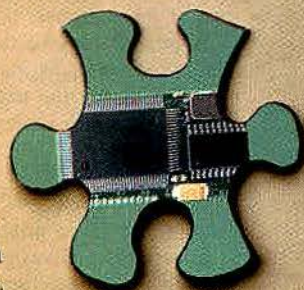
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Auction spectrum for consumer use; lease spectrum for private mobile radio networks



On Sept. 4, 1996, FCC chairman Reed Hundt spoke to the Royal Institute of International Affairs in London. In his speech, he listed seven principles that may give some insight into regulatory policies. Two groups that have been adversely affected by FCC regulation in recent years include private mobile radio service providers, as well as commercial mobile radio service providers that offer specialized mobile radio (SMR) service. If you are in one of these groups, take heed.

A printed copy of the speech takes 15 single-spaced typewritten pages, enough to fill many magazine pages, so only a few excerpts that may be representative can be included here.

Chairman Hundt:

These seven principles reflect the most important insight I've garnered from three years at the FCC: Study with scrupulous exactitude all telecom policies of historical tradition and then do the exact opposite. Examine all received wisdom and declare it to be myth. Listen to all assertions of fact and suspect they are fictions. And get yourself a good economist; then do what he or she says.

1. If a country has a single, strong national telecommunications firm, it has a big problem.

2. Any nation that champions a national telecom firm and limits foreign investment is wasting its money and turning down a big opportunity.

3. When governments intervene in markets in the name of guaranteeing universal service, they generally don't

make anything universal, and they don't enhance telecom service.

4. Every country does not need two redundant wireline networks.

5. If you're not awarding spectrum licenses by auction, you're making a big mistake. And if you're not awarding all other licenses in essentially no time and in infinite amounts, you're making a bigger mistake.

6. After you auction the licenses, let the market work.

7. The right goal for international communications is the same as the goal for domestic communications: no more regulation of communications services than of soap or software or shoes.

Principles 5 and 6, about auctions, let big business in and shut small business out, as service providers. They make virtually no provision for private mobile radio users.

The principles that Hundt articulated equate *licensing* spectrum with *allocating* spectrum. The difference is that the FCC previously decided how spectrum would be used and then issued licenses to service providers or end-users to use individual frequencies or bands of frequencies for the purpose described.

"What if the spectrum is already lightly used?" Hundt asked. "Allow auction winners to relocate the existing users at no cost, so that the market can clear spectrum," he said.

"How should the spectrum be used?" Hundt asked. "Any way the auction winners want: no restrictions; no rules; total flexibility," he said.

Manufacturing companies, mining companies, airport facility operators, transport companies, delivery services and many other enterprises that use private mobile radio for communications internal to their organizations aren't well-served, in many cases, by commercial systems built to use spectrum purchased at auction. Most of these commercial systems are intended to serve consumers, the most highly populated areas or both. Many of them don't deliver adequate coverage where current private radio users need it, and what's available typically costs more.

Private mobile radio users should be permitted to obtain licenses in exchange for paying a lease fee. Purchasing a license at auction is not practical for private mobile radio users because the coverage of

their private networks do not conform to auction regions.

"We recognize that we must pay for spectrum and suggest that a new private wireless allocation could be paid for through efficiency-based spectrum lease fees," said Launita Hernandez of Airborne Express, a private mobile radio service user. "Fees are a viable way to reimburse the federal government for the use of spectrum."

Hernandez and representatives of Northwest Airlines, Ford Motor Company, American Airlines, United Airlines and United Parcel Service visited Capitol Hill during the week of Dec. 16, 1996, to meet with staff members of the budget and telecommunications committees. An organization for which Hernandez serves as chairman, American Licensees for Ensuring Responsible Transition of Spectrum (ALERTS), is promoting the idea of lease fees. Other members include Toyota Motor Manufacturing-Kentucky, Delmarva Power Company, Federal Express and America West Airlines. Member companies own and operate internal communications systems to enhance corporate competitiveness, promote productivity and ensure the welfare of their employees, the key reasons for having a private radio communications network.

* * *

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—Don Bishop

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5-7—Vehicular Technology Conference, sponsored by IEEE Vehicular Technology Society, Hyatt Regency at Civic Plaza, Phoenix. Contact: Wendy Rochelle, 908-562-3870; Fax 908-981-1769.

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21—Radio Club of America, Communications Symposium, 88th Anniversary Dinner and Awards Presentation, New York Athletic Club, New York. Contact: Gerri Hopkins, 908-842-5070.



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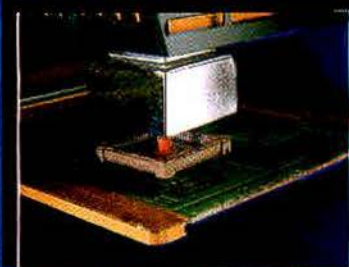


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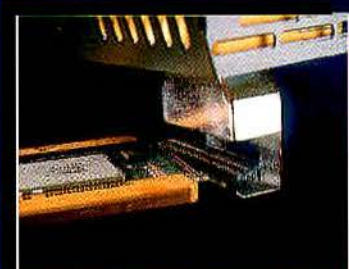
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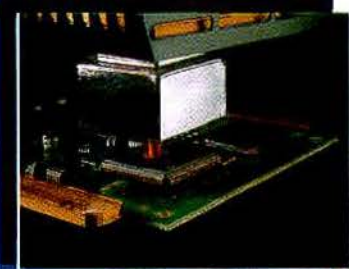
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Testing repeater sensitivity degradation

By Harold Kinley, C.E.T.

How well is your repeater performing under actual operating conditions? Unless you check the receiver sensitivity under real operating conditions, you are not getting the true picture. Antenna noise, duplexer mistuning and other on-site problems can cause the *actual* sensitivity to be far worse than the *on-bench* sensitivity figure stated in the service manual specifications. Here is how to determine just how well your repeater is performing under real-life conditions.

The "isotee"

In order to perform the necessary tests and measurements, you can make an isotee coupler from a simple "tee" connector. This is probably most easily done with a UHF connector, but it can be done with other connectors as well. An isotee connector provides a high degree of isolation between the through-line portion and the coupled port. It can be used for coupling in either direction. That is, it can be used to couple a signal *into* a transmission line from a signal source or to couple a sample of the signal *from* the transmission line into a measuring instrument such as a spectrum analyzer, frequency counter, deviation meter or other device.

Kinley, a certified electronics technician, is regional communications manager, South Carolina Forestry Commission, Spartanburg, SC. He is a member of the Radio Club of America. He is the author of *Standard Radio Communications Manual: With Instrumentation and Testing Techniques*, which is available for direct purchase. Write to 204 Tanglewylde Drive, Spartanburg, SC 29301.

The construction of a simple UHF isotee has been described in past columns in *MRT*, but it will be repeated here for the sake of those who missed those columns. The center pin of the male portion of the UHF tee connector is removed by unscrewing it from the connector. The pin is then cut with a hacksaw. Next, a slot is made into the end of the pin so that a screwdriver can be used to reinsert the pin into the connector. The slot can be cut with the hacksaw blade as well. Once the pin is reinserted into the connector, screw the connector onto a barrel or straight-through connector. This will leave you with a connector with three UHF female ports.

The barrel will be the isolated, or coupled, port. Make sure that no dc continuity exists between the isolated port and the other ports. If dc continuity exists, the pin is too long, and it should be removed and cut again to a length that will prohibit direct contact between the barrel connector and the modified tee connector.

The isolated port of the isotee connector will be isolated by 30dB–40dB from the through-line portion of the connector. You can determine the amount of isolation provided by using the setup shown in Figure 1 below left. Increase the generator signal level to produce 12dB SINAD at the receiver audio output. Record the signal generator level in dBm. Now, subtract the normal receiver sensitivity from the generator level required through the isotee. The result is the amount of isolation provided by the isotee connector. For example, if the normal receiver sensitivity is -119dBm , and the signal level required to produce 12dB SINAD through the isotee was -85dBm , then the isolation of the isotee is:

$$-85 - (-119) = -85 + 119 = 34\text{dB}$$

Be aware that the amount of isolation provided is frequency-sensitive. Thus, the isolation test should be conducted at the frequency at which you are going to be testing.

The isotee can operate in the presence of RF power and still provide enough isolation to protect sensitive devices such as signal generators from overload. Check to make sure that the instrument you are using will not be overloaded by excessive RF coming through the isolated port of the isotee.

Suppose that the output of a repeater is 100W (50dBm) and that the isotee provides 35dB of isolation. This means that the RF level getting into the attenuator pad is $50 - 35 = 15\text{dBm}$. Be sure that the signal generator or pad can handle this power level. If not, you must provide more isolation.

Checking repeater performance

There are several things that must be known in order to determine just how well a repeater is performing and how much degradation is caused by an *external* problem and how much by an *internal* problem. The external problem would be the site noise coming in through the antenna. The internal problem would be duplexer tuning and transmitter and/or receiver performance.

First, we need to know the receiver's bench sensitivity figure for 12dB SINAD. This is the basic starting point. It is easier to work with dBm than microvolts in this case. Let's suppose that the receiver has a 12dB SINAD sensitivity of -119dBm . This will serve as our basic reference point. Let's call this reference level #1.

(continued on page 48)

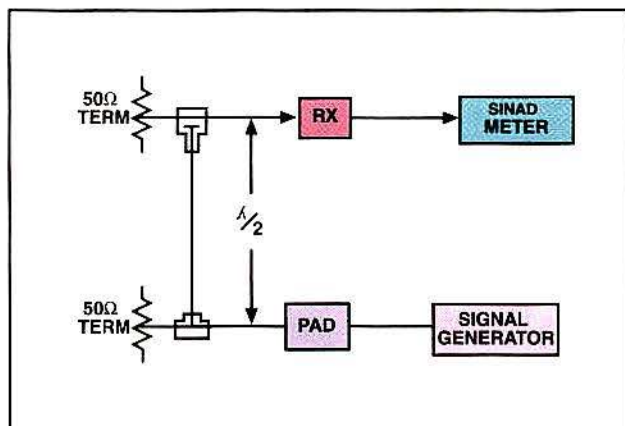


Figure 1. This setup is used to determine the amount of isolation provided by the isotee. See text for details.

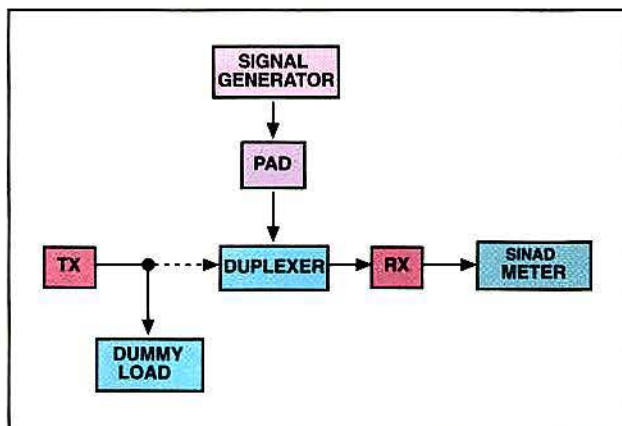


Figure 2. The insertion loss of the receiver side of the duplexer can be determined with this test setup. See text for details.

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By Donald E. Koehler

North America's communications business sector has seen explosive growth since deregulation.

Does this describe you? Your business has a modern messaging system for providing alphanumeric paging or digitized voice, and you want to expand your coverage area. You also want a platform for delivering messages to and from all areas. One answer might be to connect with a public switched telephone network (PSTN) or a private interexchange carrier (IXC) and to use frame relay technology. This transport technology moves large

amounts of digitized messages to distant transmitter sites. What will you do if the expanded coverage and service area lacks the solid, reliable PSTN system you have come to expect in urban North America?

Consider using a satellite-based system to move digital information to distant or remote sites not served by a high-quality PSTN. Satellite-based systems may offer advantages such as stable bandwidth costs for data, flexible site location options and few worries about loss of service caused by political troubles and strikes. Complex and expensive system components are not a concern with satellite data transport. Modern technology has brought changes.

The building blocks of a satellite data transmission system are:

► **Digital modem** — It produces an IF signal (typically 50MHz to 80MHz) modulated in one of several formats. Its output is delivered to an indoor unit.

► **Indoor unit (IOU) or upconverter** — It takes the IF signal and converts it to L-band frequencies between 900MHz and 1,200MHz. Its output is delivered to the outdoor unit via an interfacility link (IFL) cable, a type with extremely low loss.

► **Outdoor unit (ODU)** — It has a solid-state power amplifier and low-noise block (LNB) downconverter. Transmit power levels vary. Some units provide as much as 5W, and larger units furnish as much as 20W of RF energy to the feedhorn. The ODU is what you see with the feedhorn assembly mounted in front of the dish antenna, and it performs both transmit and receive functions. On receive-only units, this component is small, especially on Ku-band systems.

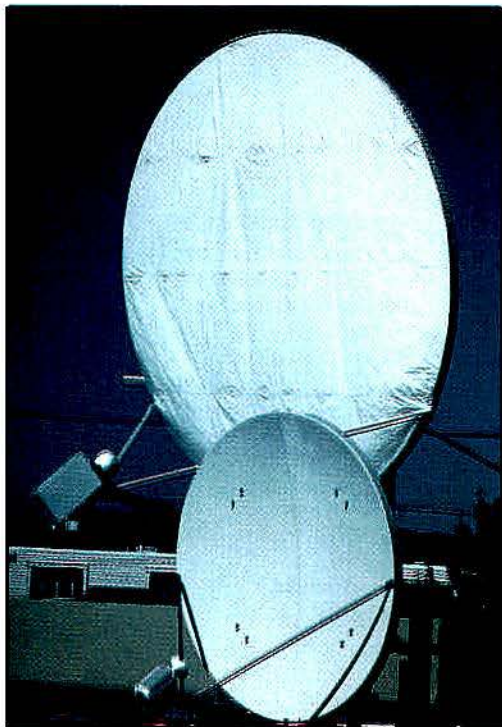
► **Antenna or dish** — Antenna

size depends on the frequency band used (C or Ku) at power levels required to reach the system's space segment reliably and the space segment's transmitter power. These power levels are, in part, driven by location. Generally, the farther north or south the earth site is from the equator, the larger the antenna needed to overcome increased path losses. This entire system, except for antenna, can be as small as an ordinary desktop PC, and it uses regular power mains.

Two types of satellite systems and network topologies are in general telecommunications use. The first is *single carrier per channel* (SCPC) with a star topology. The second is *demand-allocated, multiple-access* (DAMA) with mesh topology. Both types use geosynchronous earth-orbiting (GEO) space segments. (See Figure 1 on page 12.) Common satellite frequencies in North America are C-band (4GHz to 6GHz) and Ku-band (8GHz to 12GHz).

The following information explains how to use these components in a system. The space segment is treated as a simple "bent pipe" that ensures satisfactory data delivery at the distant earth station. This simplification does not do justice to what actually are sophisticated space systems, but it serves to focus on data traffic movement from ground site to ground site.

The first system, SCPC, commonly is used as a very small aperture terminal (VSAT). It typically has a low-power (20W or less) digital carrier and a small, truncated parabolic antenna linking the remote site to the space segment. The space segment relays the signal to a centralized hub. At the hub, data are processed and used or rebroadcast to other remote systems. Unless polled, each remote terminal requires a small



These C and Ku band antennas give an idea of the relative size of the dish required to reach a satellite.

Koehler teaches at the University of Alaska, Anchorage.

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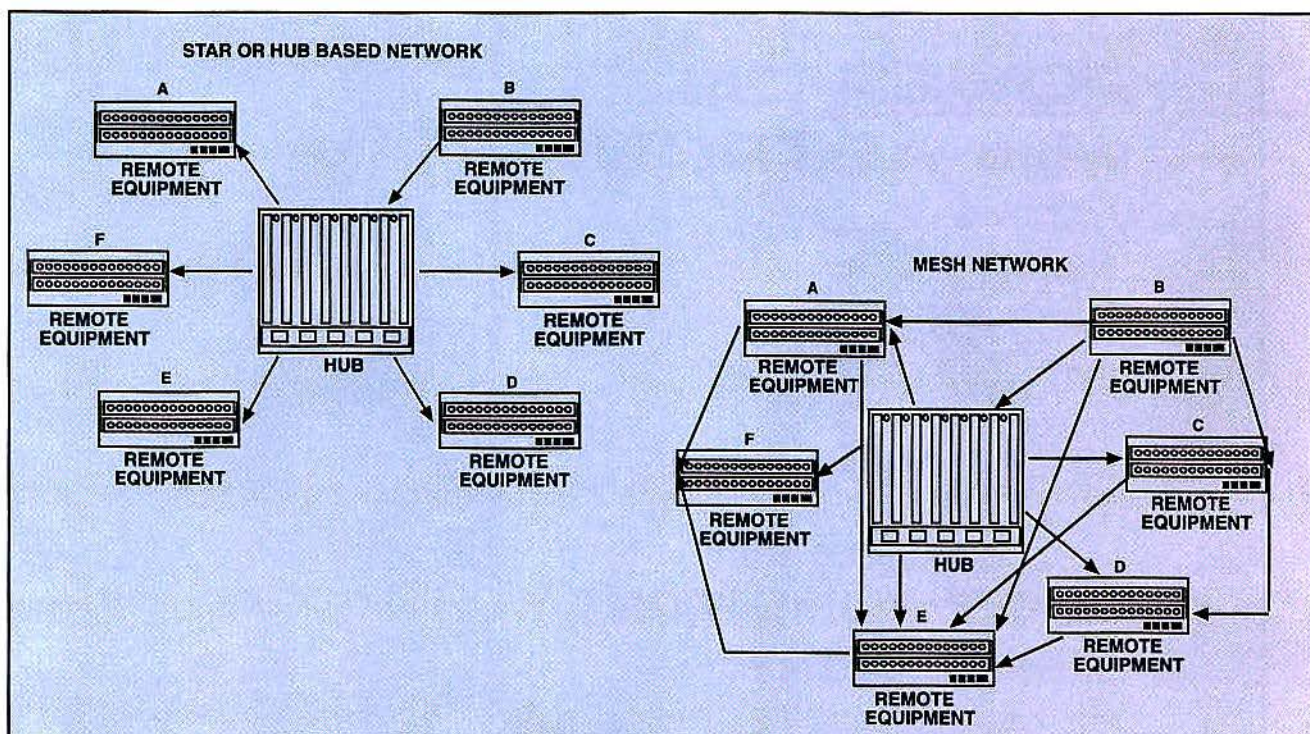


Figure 1. Two types of satellite systems and network topologies are in general telecommunications use. Left, the *single carrier per channel* (SCPC) with a star topology. Right, the *demand-allocated, multiple-access* (DAMA) with mesh topology. Both use geosynchronous earth-orbiting (GEO) space segments.

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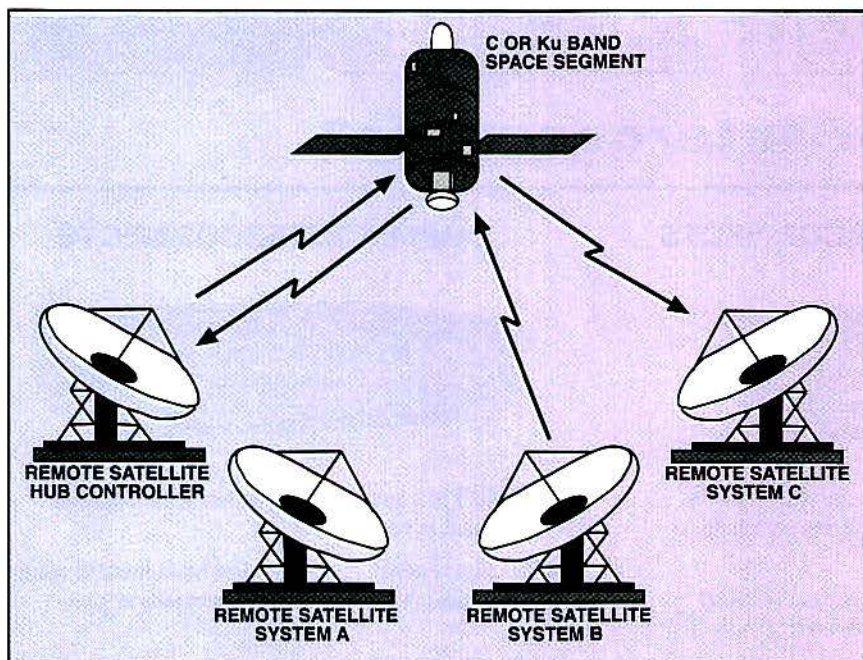


Figure 2. With SCPC system star topology, all remote-station data must go to the hub first. To send data to any other remote station, the hub must provide a link to the space segment.

amount of bandwidth permanently allocated on the space segment.

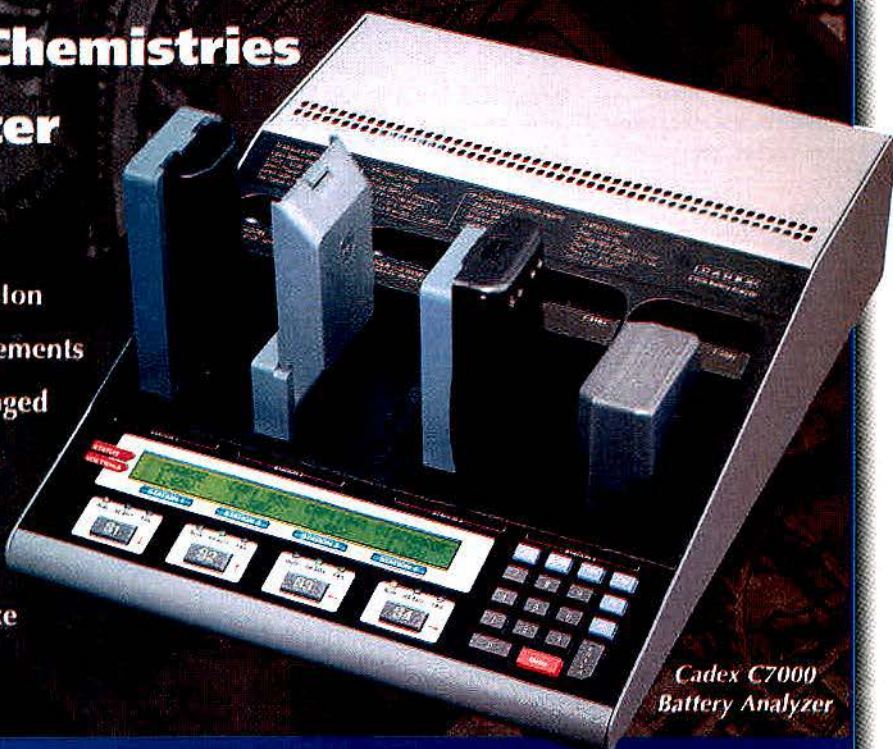
This implementation has some advantages and disadvantages. As seen in Figure 2 above (a star network), all remote-station data must go to the hub first. To

send data to any other remote station, the hub must provide a link to the space segment. Station B has data for station C, so remote station B must send data to the hub, which then retransmits it to remote station C. For a polled or broadcast application, where data transfer is continuous, where the same data are used by all ground stations or where data are returned to the remote site after centralized processing, SCPC systems using star topology may make sense. This technology is mature and robust, with a good selection of vendors able to provide the necessary components for a complete, "off-the-shelf" system package. Costs vary according to ground segment location and frequency band.

As a disadvantage, the delay incurred in this double-hop (remote up to satellite, down to hub, then up to satellite and back down to remote), made necessary by the star topology, may adversely affect time- or delay-sensitive data transfer protocols. The required permanent allocation of bandwidth on the space segment can be costly for applications with an intermittent data stream, such as with paging or messaging. Over time, the bandwidth cost on a GEO satellite system may be

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significantly higher than the entire cost of the ground segment. A newer type of equipment provides an alternative to SCPC implementation.

DAMA with mesh topology has virtually the same basic RF system building blocks as SCPC. (See Figure 3 at the right.) The difference is the amount of electronic intelligence contained within the digital satellite modem. With DAMA, each remote earth station can exchange data with the hub and, more importantly, with any other remote earth station. This communication among sites is the essence of a mesh topology system. Data can be exchanged between any two (or more) ground stations.

Implementing this topology is not as simple as Figure 3 may imply. Because data must flow over an RF link, a high-speed data protocol may require two frequencies (for a duplex circuit), but if data are sent using a bi-synchronous protocol, then only a single frequency (for a simplex circuit) is required. The implementation of DAMA mesh networking in most systems uses the hub controller as a kind of traffic cop. This controller function may require a separate, permanent frequency for passing directions to remote site terminals.

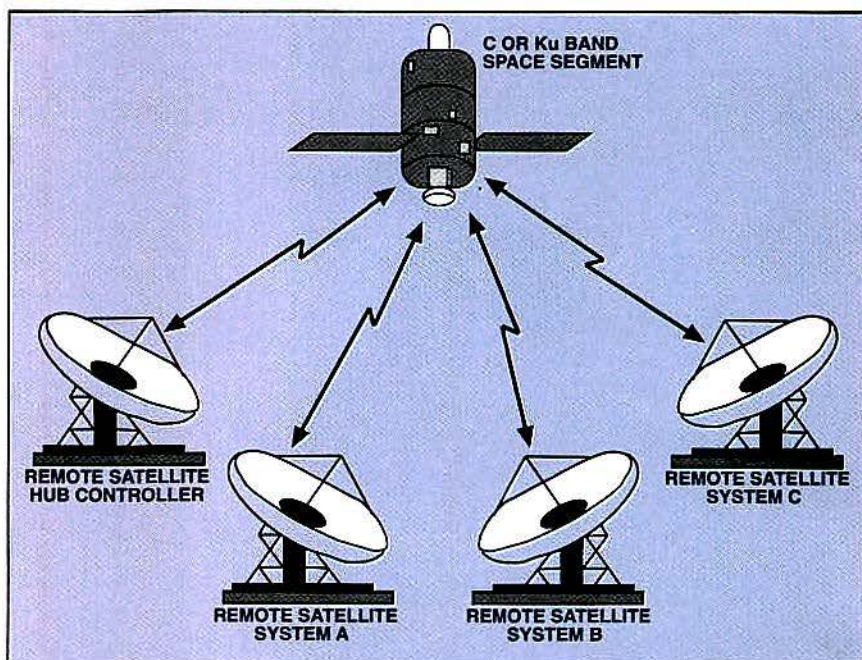


Figure 3. With DAMA system mesh topology, each remote earth station can exchange data with the hub and, more importantly, with any other remote earth station.

When, for example, remote system B has data for remote system C, system B signals the hub controller with a request

to contact remote system C. The hub controller sends data to systems B and C, directing them to "meet" on an assigned

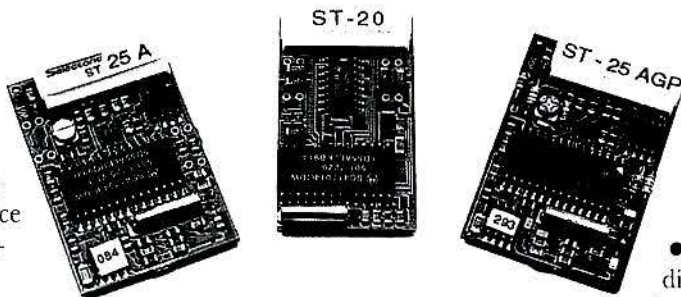
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frequency, relayed through the satellite, where the data are exchanged. When the transaction is complete, both system modems return to a common control frequency. Thus, data can be transferred between any two sites under the control of

a central hub station. It takes longer to explain this function than it takes for modern satellite modems to change frequencies and to transfer data.

Monitoring remote system status and collecting billing information can be done



Close-up of Ku band LNB/Power amplifier components.

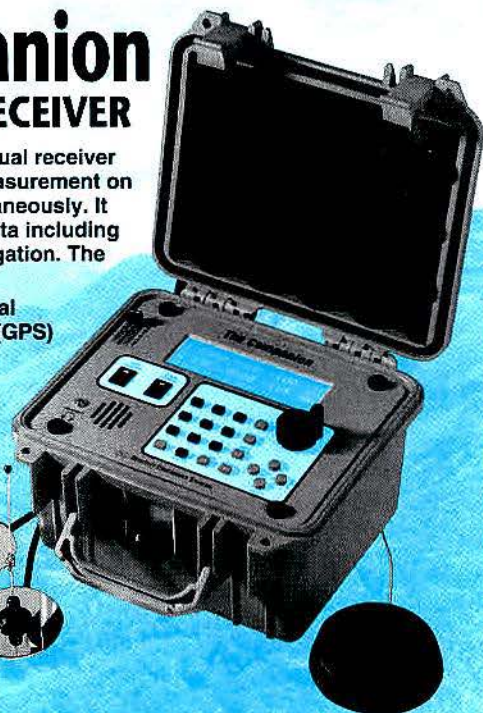
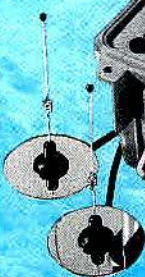
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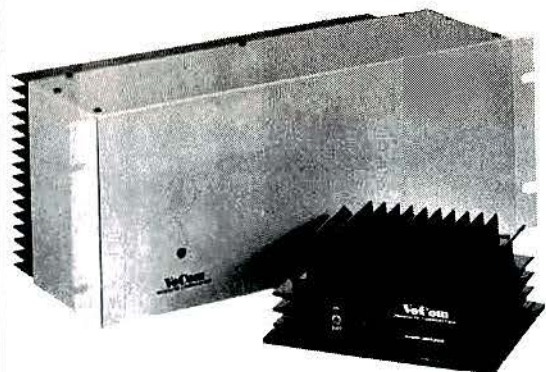
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at the control hub for either a SCPC or DAMA topology-based communications system. Each satellite system manufacturer has a different means to accomplish network control and remote messaging, so specific questions on hardware and available controller software should be directed to the manufacturers.

To extend your broadcast coverage over an extremely wide area or internationally, a receive-only satellite relay system may make sense. To extend your service area, certain types of this equipment can be upgraded simply and easily with changes to the hub controller and site modems—assuming care and planning for future growth were considered at the initial purchase. With the right kind of initial equipment purchase, the RF link portion of the system can remain the same when the system is upgraded. Modern, modular satellite communications equipment is reliable and simple for technical staff to maintain.

Acknowledgments:

Thanks to George Molezan of General Communications (GCI), Anchorage, AK, for permission and access to photograph the company antenna farm.



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The importance of coaxial cable to base station performance

Low-loss flexible cable provides an alternative to semi-rigid corrugated cable with advantages in loss, handling, ease of installation and ruggedness compensating for tradeoffs in shielding and intermod performance.

By Robert Perelman and Joe Lanoue

Coaxial cables are vital to the performance of mobile radio systems. Selecting the best coaxial cable for an application within a mobile radio base station has become more complicated over the past few years as more suppliers have offered a broader range of products. The cable selected will affect the system's cost, coverage and reliability. The new choices that are available can frequently allow for better overall system performance at a lower price than the older alternatives.

Until recently, the choices were generally limited to corrugated copper cables, conventional braided cables and air dielectric braided cables. Generally, corrugated copper cables were chosen for applications requiring the lowest loss, such as antenna feeders. Braided coax or RG-type cables were used for applications requiring the greatest physical flexibility. Air dielectric cables seemed to offer a compromise, with relatively low loss and good flexibility, but their construction leads to performance problems. These include moisture accumulation in the air space, radial movement of the center conductor at bends, resulting in VSWR degradation, and axial movement

Perelman is vice president, Global Infrastructure Equipment and Lanoue is manager of communications products at Times Microwave Systems, Wallingford, CT.



The flexible low-loss cables are available in a range of sizes from 0.195" to 1.70" diameters for a wide range of applications from mobile antenna feeders and system interconnects to base antenna feeders.

of the center conductor relative to the outer conductor, resulting in connector failures.

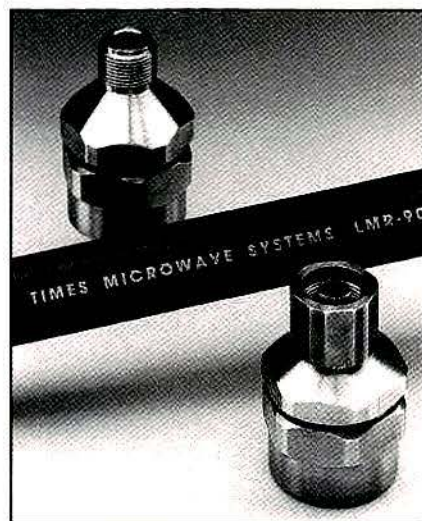
In recent years, several new types of cables have been introduced for communications applications. These include low-loss flexible cables, which offer loss comparable to corrugated copper cables, but with much better flexibility. In addition, several manufacturers have introduced new types of semi-rigid cables with smooth outer conductors. New suppliers of corrugated copper cable have also entered the market. To select from this greatly expanded universe of choices, it is helpful to consider the most

important characteristics of coaxial cable more carefully.

Signal Loss

Because the function of a coaxial cable is to transmit RF energy from one point in a system to another, efficiency is the most important factor in selecting a cable. The loss of a cable is measured in dB/100ft, which is a logarithmic expression of the ratio of the output power from the cable to the input power to the cable. The loss of a cable is determined by the conductor loss and the dielectric loss. Dielectric loss remains essentially constant as the size of the cable changes, whereas conductor loss decreases as cable size increases, much as the resistance of a wire decreases as the size of the wire increases. The need for low loss, rather than requirements for high power handling, dictates the size of large cables in mobile communications systems.

Because all of the cable types being



The 5/8" low-loss cable eliminates the need for jumper cables in base antenna feeder applications resulting in comparable loss to 7/8" cable with jumper cables.

Table 1—Transmission performance comparison (dB per 100 feet).

Frequency (MHz)	Times LMR-1200 7/8"	Cablewave FLC78 7/8"	Eupen 5228 7/8"	Andrew LDF5 7/8"	CommScope CR501070 7/8"	Times LMR-900 5/8"
450	1.15	0.850	0.810	0.834	0.790	1.10
900	1.67	1.25	1.21	1.23	1.21	1.60
2000	2.59	2.10	1.94	1.97	1.97	2.49

Source: Manufacturers' published data.



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Table 2—Assumptions: jumpers are 6 feet in length, the operating frequency = 2,000MHz and there is a 0.06dB loss per connector.

Performance Details:

Flexible 5/8" low-loss cable (LMR9-900) —jumpers not required
 Transmission line loss = $(2 \times 0.06\text{dB}) + (150 \times 0.026) = 4.02\text{dB}$
 List price = 150 feet \times \$3.70/ft + \$45/connector = \$645

Flexible 7/8" low-loss cable (LMR-1200) —jumpers not required
 Transmission line loss = $(2 \times 0.06\text{dB}) + (150 \times 0.02) = 3.12\text{dB}$
 List price = 150 feet \times \$4.85/ft + \$65/connector = \$857.50

Semi-rigid 7/8" corrugated copper cable LDF5 —with 1/2" (LDF4) jumpers
 Transmission line loss = $(2 \times 0.06\text{dB}) + (2 \times 0.4) + (138 \times 0.02) = 3.68\text{dB}$
 List price = 138 feet \times \$6.18/ft + \$96/connector = \$110/jumper = \$1,264.84

Flexible 1 1/4" low-loss cable (LMR1700) —with LMR-900 jumpers
 Transmission line loss = $(2 \times 0.06\text{dB}) + (2 \times 0.28) + (138 \times 0.015) = 2.75\text{dB}$
 List price = 138 feet \times \$7.80/ft + \$110/connector + \$142/jumper = \$1,580.40

Semi-rigid 1 1/4" corrugated copper cable LDF6 —with 1/2" (LDF4) jumpers
 Transmission line loss = $(2 \times 0.06\text{dB}) + (2 \times 0.4) + (138 \times 0.015) = 2.99\text{dB}$
 List price = 138 feet \times \$10.94/ft + \$150/connector + \$110/jumper = \$2,029.72

compared use low-loss dielectrics and high-conductivity conductors, the losses of similar size cables are close, as can be seen in Table 1 on page 20. This is not the entire story with regard to total signal loss, because the semi-rigid cables gener-

ally require the use of jumper cables at each end in order to be routed to the radio equipment and the antenna. These jumper cables add loss to the feeder run. Flexible cables generally can be run without jumper cables, lowering total signal loss,

or alternatively, allowing the use of a smaller cable to achieve the same loss.

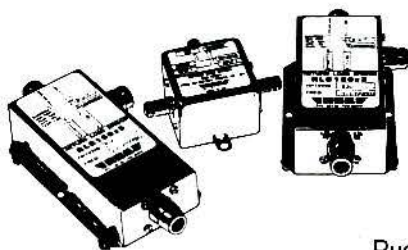
Table 2 at the left shows a performance comparison of 150-foot feeder runs of flexible and semi-rigid cables.

By eliminating jumper cables with the 5/8" and 7/8" flexible low-loss cables, performance similar to the next-larger-size corrugated copper cables can be achieved with substantial cost savings. The elimination of four connector junctions—two on each of the jumper cables—greatly increases the reliability of the system while simplifying and speeding installation. These savings are being realized by system operators who have chosen the 5/8" flexible cable to replace 7/8" corrugated copper cables. The difference in total signal loss is only a few tenths of a decibel for lengths as long as 200 feet, an insignificant difference in system performance. The cost savings are about 50% in materials and a substantial savings in labor. An additional savings may result from the reduction in tower loading with the use of smaller cable.

Shielding

Another important characteristic of a coaxial cable is shielding effectiveness.

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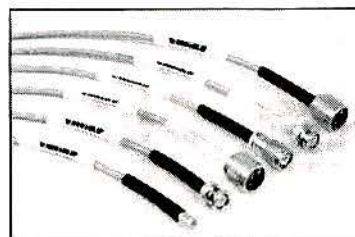
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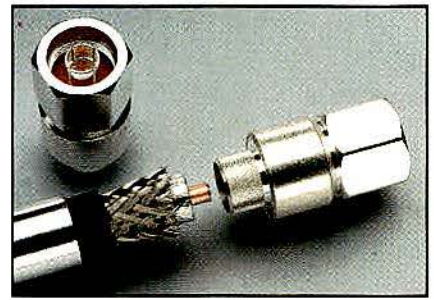
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This is a measure of the ability of the cable to keep signals in the cable from leaking out and signals outside the cable from leaking into the cable. A transmit cable with poor shielding may allow RF energy to leak out and interfere with nearby receive cables. Conversely, a poorly shielded receive cable will allow RF energy from the environment into the system and may cause interference. Typically for antenna feeders, shielding is not

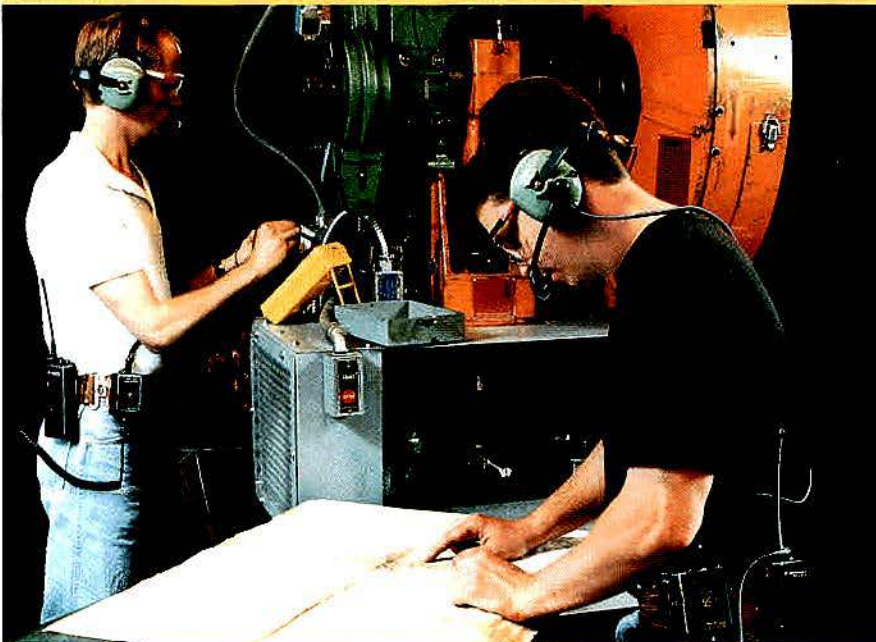
an important issue because the antennas allow a large range of RF signals into the system, which must be filtered out before the receiver.

Semi-rigid cables with solid outer conductors provide the best shielding, typically better than 120dB. Flexible, low-loss cables have bonded metal tape outer conductors with braided overshields. This construction provides better than 90dB shielding. With either semi-rigid or flex-



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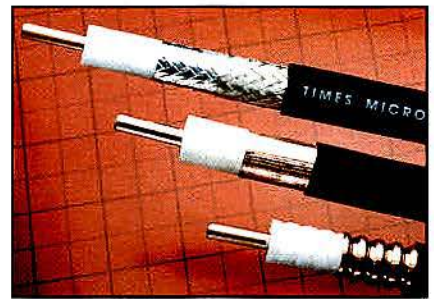
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The 1/2" varieties of the low-loss flexible cable, the smooth-wall copper cable and the corrugated copper cable.

ible cables, the weak point in shielding is the interface between the cable and the connector, which will typically limit shielding to about 90dB.

Because the concern is typically the leakage of signal from a transmit cable into a receive cable, the effective shielding provided is the sum of the shielding of the two cables—better than 240dB in the case of semi-rigid cables or 180dB in the case of flexible cables. These levels result in signals that are far below the receiver sensitivities of any practical mobile radio system. In any case, these cables are being used to feed antennas. Typically, the isolation between receive and transmit antennas will be far less than the isolation between the cables; therefore, cable shielding is not the limiting factor in these applications.

Intermodulation distortion

Intermodulation distortion or passive intermodulation distortion (PIM) has been a topic of much discussion in recent years as a contributor to performance degradation in mobile radio systems. When two high-power signals are present in a device with a non-linear junction (such as a semiconductor or ferro-magnetic material), a third signal is generated at a frequency equal to two times one of the frequencies minus the other frequency (sometimes referred to as $2A - B$). Actually, a whole

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Communications Decoding

The Xplorer's 2 line LCD can selectively switch between CTCSS, DCS, and DTMF displays.



CTCSS Display



DCS Display



DTMF Display

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Freq. Response: 50 - 3000Hz
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Input: 50Ohm, -59dBm @100MHz
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series of additional frequencies will be created, with the 2A-B frequency being referred to as the third-order intermod product. In high-power systems, such as broadcast, the power levels of the intermod signals can be quite high relative to receive signals and can cause major problems with other co-located systems. Within mobile communications systems, the power levels are relatively low, and the frequencies that are used are

usually selected to minimize the probability of within-system interference from intermodulation. The primary concern is active devices that usually produce intermodulation products at levels much higher than passive devices, such as cables.

PIM levels are typically expressed in dBc (decibels below the carrier level). The following estimated values are based on two carrier tests with carriers in the 900MHz range at +43dBm (20W)

Semi-rigid cables with properly designed and attached connectors can provide PIM levels of -160dBc and better. Flexible low-loss cables, with properly designed and attached connectors, provide PIM levels of -130dBc or better. The limitation in both cases is the connector-to-cable interface and the design of the connector.

These levels are far better than the levels provided by typical active components, such as power amplifiers, and are more-than-adequate for most system applications. In the most-common system configuration, additional protection for the receiver is provided by the use of separate receive and transmit antennas. The separation of the antennas results in at least 60dB of path loss, which reduces the level of the intermod products in the receive path. In systems using the same antenna and transmission line for transmitting and receiving, the additional path loss is not available, and the immunity of the system to intermod is decreased.

VSWR

VSWR is one way to express the amount of the power directed toward a device that is reflected back to the input. Other ways of expressing this phenomenon are reflection coefficient and return loss. In any case, achieving low values of reflected power depends on maintaining constant impedance along the length of the device. In a cable, low reflected power is important for proper system performance and is also used as a "figure of merit," with lower values of reflection corresponding with "better" cables.

Achieving low values of VSWR in a cable depends on proper design of the cable to achieve the desired impedance (in the case of wireless communications, typically 50Ω). This characteristic impedance is determined by the relative dimensions of the inner and outer conductors and the *dielectric constant* or *velocity of propagation* of the dielectric. In addition, impedance variations along the length of the cable, especially those that occur at evenly spaced distances along the length of the cable can result in high reflections at specific frequencies, because of an additive effect. These periodic variations can be introduced in the manufacturing process by gears, pulleys, or any other moving part.

Typically, all of the cable types described can be provided with VSWRs of 1.3 or better over specific communications bands—more than adequate for most applications.

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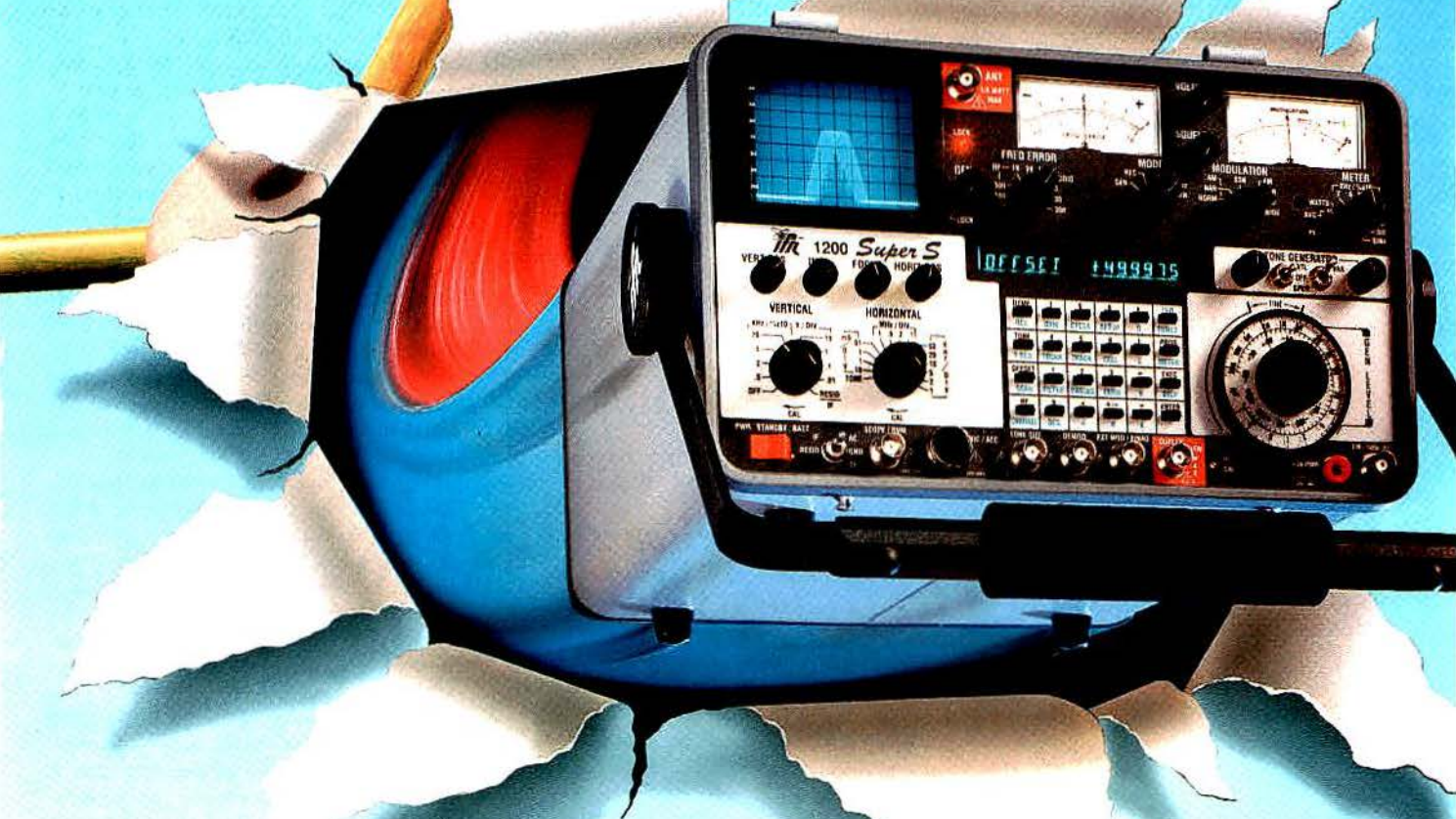
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ments, the ability of the cable to withstand environmental extremes over a long time is critical. This includes temperature extremes, humidity and water, UV radiation, vibration from the wind and the loading of ice and snow. Semi-rigid corrugated copper cables have a long history of successful service in many thousands of tower installations. The flexible low-loss cables have been used in tower applications for more than three years in a broad

range of climatic conditions with success. Their construction is based on materials used in cable TV applications for more than 20 years. The other smooth-wall, semi-rigid cables mentioned are also based on cable TV technology.

For installations requiring direct burial, or in especially severe environments, flexible low-loss cables are available in versions with a flooding material included in the braid. This prevents any

moisture that enters the cable because of damage to the jacket or poorly sealed connectors from traveling along the length of the cable.

Installation time and cost

Semi-rigid corrugated cables can be difficult to install, especially where they must be routed in tight spaces, including building-top sites and monopole towers. Flexible low-loss cables can be routed much more easily because of their substantially lower bending moments. Flexible low-loss cables are also virtually immune to kinking, even if they are bent on a tighter radius than their minimum bend radius. This is because they get their strength from thick polyethylene jackets rather than from a thick metal outer conductor. Because polyethylene is a resilient material, flexible low-loss cables are much less subject to damage than the solid-metal outer conductor semi-rigid cables.

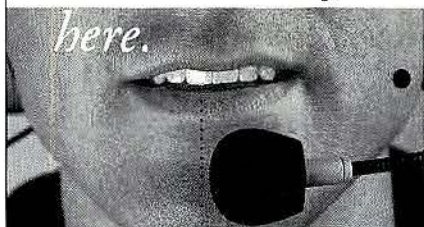
For 7/8" and 1 1/4" diameters, flexible low-loss cables actually have higher crush strength than a corrugated copper cable. At these sizes, with the low-density foam dielectric used and thin copper-tube center conductors, corrugated copper cables are quite susceptible to kinking and crushing, whereas the low-loss flexible cables are much more rugged.

The installation of connectors on the low-loss flexible cables can be accomplished in a fraction of the time that it takes to install a connector on a corrugated copper cable. Trim tools are available for the low-loss flexible cables to trim them back to the proper dimensions for connector attachment. The attachment of the connectors for the 5/8" and larger flexible low-loss cables can then be completed in less than 2 minutes per connector. This process can be time-consuming for a semi-rigid cable and may require expensive special tooling, especially in the case of the smooth wall copper cable.

Conclusion

Low-loss flexible cable provides an alternative to semi-rigid corrugated cable with advantages in loss, handling, ease of installation and ruggedness. Although there are tradeoffs in shielding and intermod performance compared to semi-rigid cables, their performance is more than adequate for most mobile radio applications. These cables are being used in antenna feeder and system interconnect applications by more and more original equipment manufacturers and system operators worldwide.

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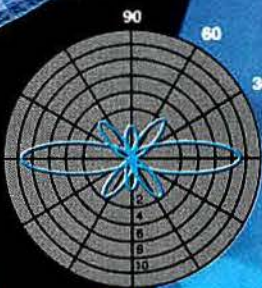
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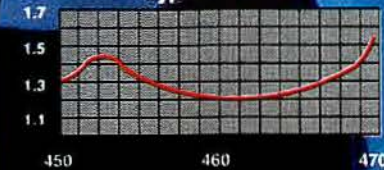


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VSWR

Typical VSWR



dBd

Gain (Relative to 1/2 Dipole)



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Open digital integrated technology for wide-area networks

Increasing demands for larger, more complex wireless communication systems strain the capabilities of existing radio system architectures. Open digital integrated radio network technology gives communication managers a migration path to an advanced radio system that provides flexible system topology, adaptable network components and the ability to accommodate many radio frequencies and protocols.

by Dave Swanson

Since the invention of trunked two-way radio in the mid-1970s, the size of radio communication systems has grown at a remarkable rate. An average system used to provide local coverage for 100 subscriber radios. Today, county-wide systems serving several hundreds of radios are routine. Vast state-wide and regional systems with thousands of subscribers are becoming the norm. In public safety, there's a growing need for agencies with overlapping geographic areas to share resources. As communication managers

Swanson is Manager of Communications for E.F. Johnson, Burnsville, MN.

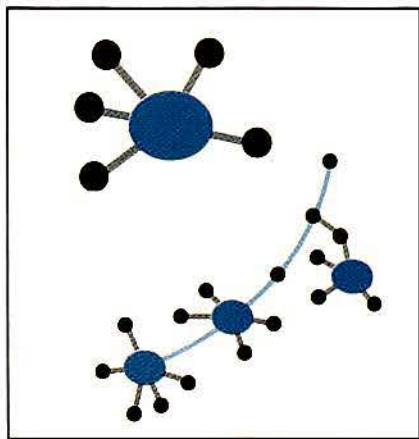


Figure 1. Most of today's trunked radio systems employ a hub-and-spoke arrangement of repeater sites connected by dedicated links to a central site (top). Open architecture allows any number of central and remote sites to be networked in any arrangement, with system control either centralized or distributed across the network (bottom).

plan larger systems, they're looking for ways to maximize over-the-air resources, minimize the cost of networking those radio resources, allow for change, and migrate to future standards and technologies.

What works, what doesn't

Most of today's trunked radio systems employ a common topology: a hub-and-spoke arrangement of repeater sites connected by dedicated links to a central site, as shown in Figure 1 below left. On our company's current wide-area trunking system, the hub is called the radio network terminal (RNT). The RNT provides central control and switching between the sites, as well as support for dispatch consoles, telco interconnects and system management.

Trunked systems can be channel-efficient and link-efficient, but closed architecture has its limits. As our engineers and product managers began to design the company's next generation of trunking systems, they realized that communication managers will need greater network flexibility. The hub-and-spoke network topology doesn't fit every application, and often it isn't the most efficient use of network resources. Tighter budgets, especially for public safety departments, have focused attention on the total cost of a radio system, including the network. That pointed our team toward designing modular radio network components, adaptable to many different network configurations. Uncertainties surrounding frequency allocations and upcoming radio technologies meant creating an open

¹The open digital integrated network described in this article is a proprietary system developed by E.F. Johnson, which it has trademarked under the name ODIN.

architecture that could accommodate just about any radio band and protocol.

The result is an open digital integrated network for radio communications.¹

An adaptable network

Our new radio network technology provides open architecture and flexible topology to build wide-area radio systems for just about any application. A system can be designed to meet specific performance levels, special requirements such as fault tolerance or economic restrictions.

The open architecture radio system is built from modular components that can work independently but share necessary information to allow wide-area subscriber roaming. The system can operate in analog and digital modes, handling voice and data traffic, and it is frequency- and protocol-independent. The system is backward-compatible to conventional and trunking system protocols and equipment. The system is also forward-compatible to emerging radio technologies and compliant with APCO Project 25 requirements. So, digital UHF APCO Project 25, analog 800MHz Multi-Net trunking and analog low-band conventional communications can be combined on the same radio network.

Instead of one hub-and-spoke system, any number of central and remote sites can be networked in any arrangement, as shown in Figure 1 at the left. System control can be centralized or distributed across the network. Links can be dedicated, or on-demand. Networking is also scaleable: start with a small system, then expand and re-arrange the system as communication needs change.

Architecture

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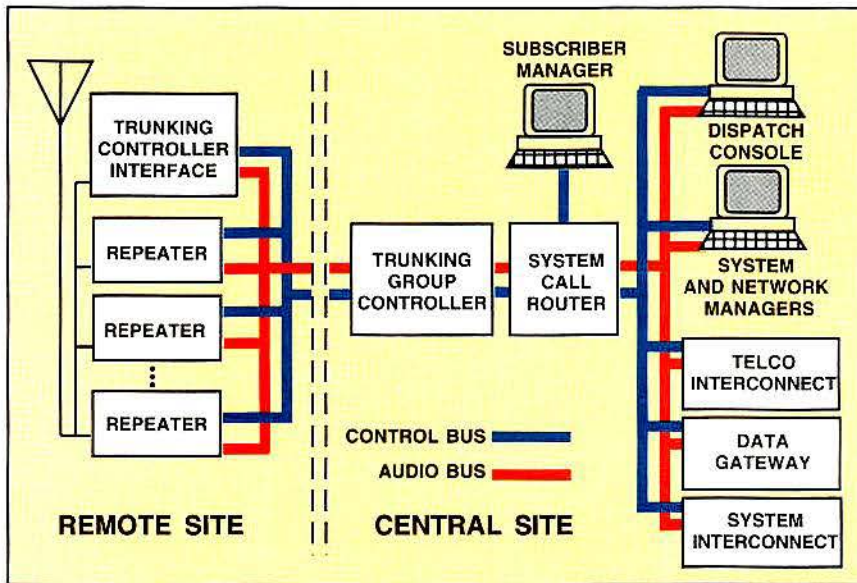


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One configuration for an open digital network system situates the trunking group controller (TGC) (for managing repeaters at a remote site) at the central site. It communicates over dedicated links. If there was no system call router, the subscriber manager could connect directly to the TGC via Ethernet.

components—both hardware and software—based on proven network technologies. Wherever possible, our team has incorporated familiar industry standards, such as TCP/IP network links between sites, and Microsoft Windows NT-based system management software.

The core of the wide-area system consists of some basic building blocks: the *trunking controller interface* (TCI), the *trunking group controller* (TGC) and (as needed) the *system call router*. The exact type, quantity and configuration of these components depends entirely on the individual system's design. Through these

hardware components, a suite of micro-computer-based system management programs direct the entire system, from setting user access to testing a microwave link. Once the core system is built, options include system applications, data gateways, telco interconnects and interconnects to other radio systems.

Network core

The core components begin with the TCI. This logic card plugs inside each of the Johnson 2000 series modular repeaters at a site. The TCI controls the trunking process at the site and manages the

high-speed data bus between the repeaters. It also serves as the common interface to the TGC, translating whatever radio protocols the repeaters are using into standard network messages.

The TGC is the interface and controller between repeater groups and call routers and other site link equipment. The unit consists of independent modules, each controlling as many as five repeaters. One TGC can control 30 channels, and multiple TGCs can be directly connected to manage very large systems. The TGC handles call processing tasks such as user and group validation, site authorization and wide-area group routing.

The *system call router* is only required as radio system design dictates. It provides wide-area call routing when trunking dedicated links, and it may control audio switching between sites for systems with more than 30 channels. The system call router is also the gateway to applications and interconnects to the outside world.

These core components communicate with each other via one or both of two open-architecture paths. The *system control bus* carries status and control information about users and network resources throughout the network. The system control bus uses TCP/IP protocols for communication. Within a site, the system bus is a 10Base-T Ethernet line running at 10Mbps. Between sites, the system bus uses frequency-shift keying (FSK) blank-and-burst or an Ethernet link running from 9.6kbps to 56.0 kbps.

The *system audio bus* carries all the system audio between TGCs, call routers, dispatch consoles, telephone interconnects and similar equipment. For intrasite

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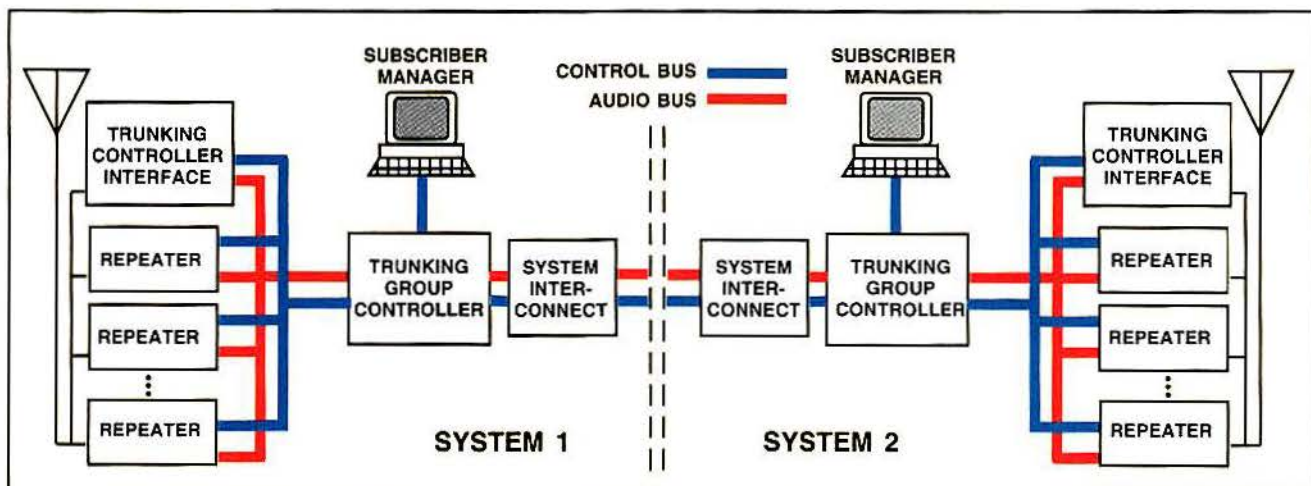
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In this configuration, two remote systems can communicate directly through on-demand circuits such as ISDN.

control, the system audio bus is an E1 (time-division multiplex) bus. Between sites, the audio bus can be linked by various analog or digital methods, depending on the client's link capacity.

Network management and applications

Since the network can combine many radio systems and thousands of users,

powerful management tools are a must. The network management software is a suite of three programs that can reside on one or different microcomputers. These managers communicate with the network at any location that has access to the system control bus, either through a dedicated TCP/IP connection (such as an Ethernet line to the TGC) or through a

remote dialup.

The *subscriber manager* is the only required management component. This software package controls the radio system's subscriber data bases. It manages user privileges and sets each user's capability level for site roaming, telephone interconnect calls and call priority. The subscriber manager can provide over-the-air

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programming of radios to dynamically assign new capabilities to subscriber radios, and it can flash-program new features into the radios. The subscriber manager also controls emergency regrouping of radios and captures all user traffic data and accounting information.

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The network can support a wide variety of applications. Its Windows-based dispatch console allows computer-aided dispatch and 911 interfaces across distributed positions. The telephone interconnect works with digital (T1, E1, DS0 or ISDN), or analog (2- or 4-wire) links. It also can provide voice mail, voice paging and call forwarding. For mobile data applications, data can be transported through TCP/IP, SNA, and X.25 gateways. Through the system interconnect, the network can interface with other Johnson radio systems and Project 25 systems from other vendors.

Migration Routes

The radio network technology also allows migration. For example, let's say you want to migrate from a 450MHz conventional radio system for public safety to a Project 25-compliant trunking system. You could begin by adding open digital system components to gain networking features. Then you would switch to repeaters that are 12.5 kHz-ready and digital-ready for Project 25. The third step would be replacement of subscriber radios with Project 25-compliant units as your needs and budget permit. With the network in place, your conventional and Project 25 radios would communicate to each other on one seamless system.

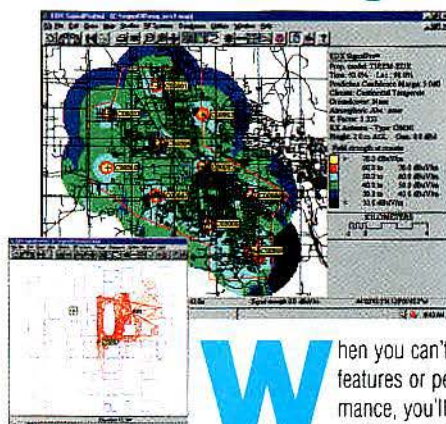
A carefully managed migration not only means minimum disruption to your system users, it can also minimize disruption of your budget. Open architecture is geared to the realities of system funding, especially for public agencies. Instead of spending a huge amount of money up front, you can time each phase of the migration to fit each funding period.

Conclusion

An open digital integrated network offers choices to communication managers, system planners, consultants, or purchasing agents, including flexibility, compatibility, features and growth potential. It allows them to dictate the structure of a radio system instead of the system dictating to them.



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Coverage prediction for digital mobile systems

Part 1—Propagation analysis to predict and to combat impairments to digital radio system signals relies on different types of models. Software tools allow system designers to evaluate configurations without expensive field measurements.

by Harry R. Anderson, Ph.D., P.E.

The rapid growth in mobile communications systems over the past several years has lead to increasing use of digital modulation techniques to transmit information. Whether it's cellular, PCS, paging, two-way mobile or SMR trunking, essentially every aspect of mobile communication has been affected by the "digital revolution." Digital techniques allow much greater flexibility for encoding and processing information, which makes possible more efficient and robust transmission than previously achieved with analog systems.

In designing any radio system, a fundamental task is to predict the coverage of a proposed system and to determine whether the intended service objectives are met. Over the years a wide variety of approaches have been developed to predict coverage using what are known as *propagation models*. Propagation in this context simply means the transfer or transmission of signals from the transmitter to the receiver. Propagation modeling is an effort to predict what happens to

signals en route from the transmitter to the receiver. Obviously the signal gets weaker, and everyone has experienced other signal impairments such as multipath fading. In large part, the design of modulation techniques and radio system hardware, including antennas, is directed toward combating the signal impairments that happen during propagation.

The traditional approaches to propagation modeling, which have been developed for analog systems, were intended only to predict signal attenuation, or path loss, as the signal traveled from the transmitter to the receiver. While these approaches have been adequate for most analog systems, digital systems need new techniques to produce other information in addition to path loss. This information may actually be the controlling factor on system performance or coverage, even when the signal-to-noise ratio is well above the value otherwise necessary to achieve perfect reception.

In the following sections of this article, various approaches to propagation modeling will be discussed with a view toward their strengths and weaknesses when used with digital systems. The most incisive approach based on ray-tracing techniques will be used to explore some of the propagation factors which specifically affect digital system

performance and coverage.

Empirical vs. physical models

The most common approaches to propagation modeling are:

- empirical models that use measurement data to define a model path loss equation.
- physical models of path loss that use physical radio wave principles such as free space transmission, reflection or diffraction.

► *Empirical Models* — In the VHF/UHF frequency bands, examples of empirical propagation models are the FCC and ITU-R models (see References). The FCC uses propagation curves that were fitted to a set of signal strength measurements done at several locations in the United States. The propagation model as represented by a set of curves for different frequency bands shows field strength vs. distance for a range of transmit antenna height above average terrain (HAAT) values. The ITU-R has similar curves based on HAAT as set forth in Rec. 370-6. The ITU-R method also provides for corrections to take into account "terrain roughness" or Δh , the 10% to 90% inter-decile terrain variation over the path. These models make use of measurement data instead of electromagnetic wave principles to define the prediction. As

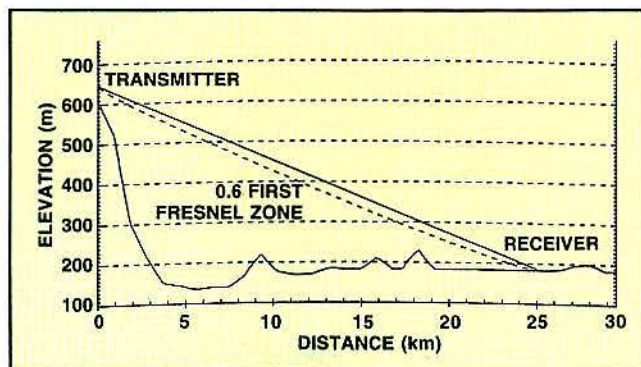


Figure 1. Line-of-sight radio path over a terrain profile.

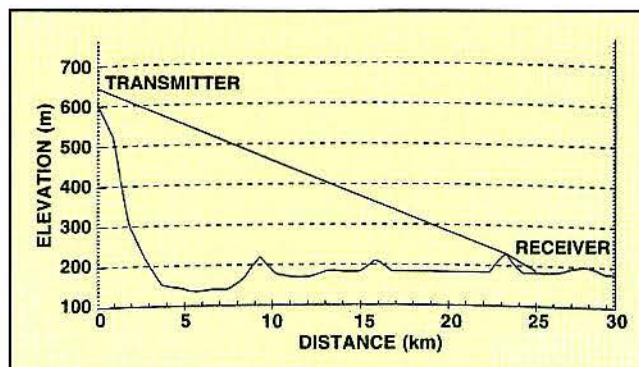


Figure 2. Obstructed radio path over a terrain profile.

Anderson is president and chief executive officer of EDX Engineering, Eugene, OR.

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such, the FCC and ITU-R models are classic examples of purely empirical models.

Another model commonly used in mobile radio and cellular work is the Hata model, which is a set of equations based on measurements and graphs developed by Okumura. This is also an excellent example of an empirical model.

Empirical models use what are known as "predictors" or "specifiers" in general statistical modeling theory. Predictors are parameters which have been found through statistical analysis to bear a relationship to (are correlated with) the quantity which is to be predicted. In econometric models, the objective may be to predict gross national product (GNP). In doing so, the model may use values such as unemployment, disposable income or balance of trade as predictors. All of these factors may have been found to be correlated with GNP, but none of them directly *causes* GNP to go up or down. Similarly, in the field of psychology, one may find a correlation between a child's IQ and the family annual income, but higher family income does not cause the child's IQ to be higher. There are other mechanisms at work. In medicine, misinterpretation of the significance of empirical studies have lead

to such absurd headlines as "Coffee causes cancer." The textbook axiom is "*Correlation does not prove causality.*"

In the case of the FCC model, through statistical analysis, a correlation was found between antenna HAAT and signal strength. But this was only correlation, not a causal relationship. Indeed, one could not conceive of a radio propagation mechanism where the simple average elevation value directly changes the magnitude of an electric or magnetic field at the receiver. The consequence of this approach is easily illustrated in Figures 1 and 2 on page 38, which show two terrain profiles along a 25km path separating the transmitter and receiver. The 3km-16 km HAAT values (as specified in the FCC Rules) for the transmit and receive antennas are the same for both terrain profiles in Figures 1 and 2, but the field strength at the receiver will be much lower in Figure 2 due to the obstruction of the nearby hill. A similar example could be constructed for Δh in which a valley and a mountain along two paths both have the same inter-decile elevation variation, yet the field strength at the receiver on the path with the mountain will be much lower than on the path with the valley. The in-

ability to explicitly account for particular features of the propagation environment is perhaps the greatest limitation of empirical, measurement-based models.

The accuracy and usefulness of such empirical models also depends on the environment where the original data for the model was taken and how universally applicable that environment is. A common problem is trying to use empirical models in areas where the propagation environment is widely different from the environment where the data was gathered. In the Hata model based on the work of Okumura, propagation path loss is defined for "urban," "suburban" and "open" environments. These correction factors in Okumura's work are an effort to refine the predictions, but unless the characteristics of "urban," "suburban," and "open" for your study area are reasonably similar to those in Japan, where the measurement data was taken, these finer-grained classifications may not be of much use.

In spite of their limitations, empirical models such as the FCC, ITU-R, and Hata models are still widely used because they are simple and allow rapid computer calculation. They also have a certain "comfort" factor in that people using them

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in certain circumstances over time have come to know what to expect and to make their own ad-hoc "corrections" to the prediction values provided by the model. When the propagation environment is fairly homogeneous and similar to the environment where the model measurements were taken, an empirical model can achieve reasonably good prediction results.

With the recent advent of automated field strength measurement systems with GPS position logging, it is now relatively easy to acquire vast amounts of measurement data. This has led to the use of custom empirical propagation models that are path-loss equations or formulas "tuned" for a given system, or even for a given transmitter or cell base station within a system. With such extensive use of measurement results, however, it is appropriate to question whether these models are really prediction methods at all, when in essence the answers are used to "predict" the answers. In spite of their heavy reliance on measurement data, such customized models will still fail to adequately account for propagation environment features such as the hill in Figure 2.

Digital communication systems require a wider variety of information from

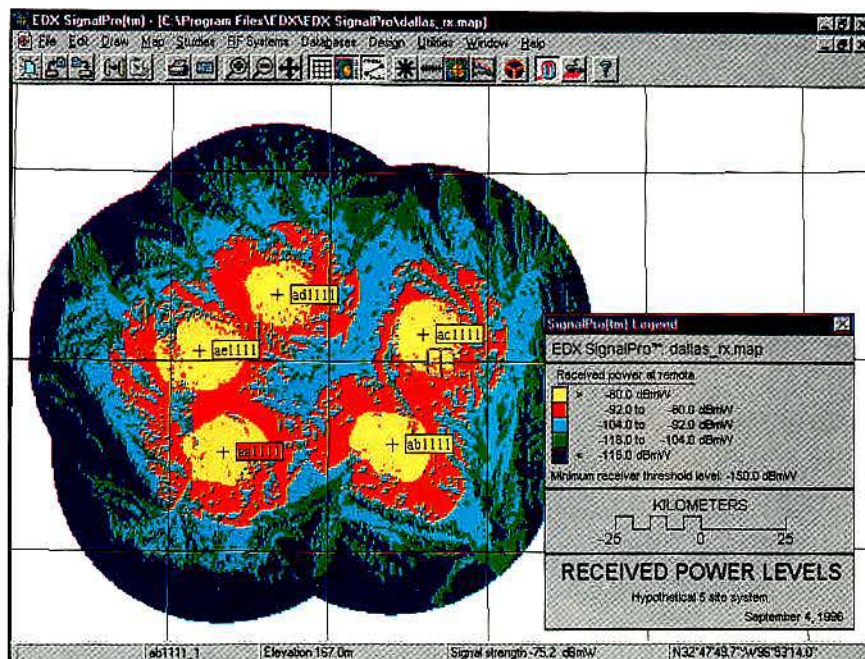


Figure 3. Received power prediction using a single path model.

propagation models than just signal strength to predict coverage and performance. With empirical models, each new

category of information represents another set of measurements that has to be taken. As an example, RMS delay

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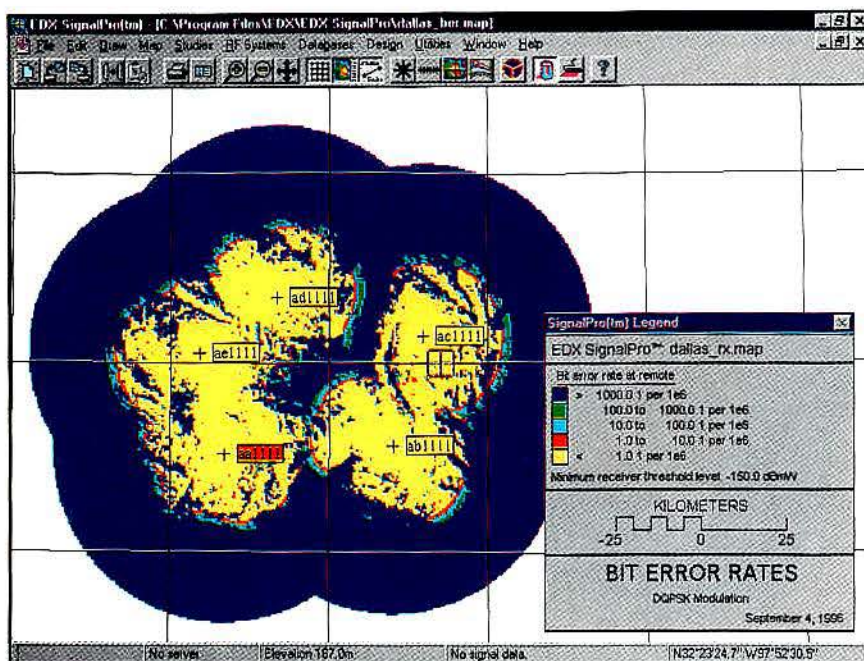


Figure 4. Bit-error-rate prediction.

spread (defined later) has recently become a routinely used factor in predicting the performance of wideband digital commu-

nication systems. For an empirical model to be useful for such systems, another set of measurement data using a channel

sounder would have to be acquired and appropriate statistical analysis would have to be done to determine statistically significant predictors of RMS delay spread. All the same limitations of empirical modeling pointed out above would still apply, but when signal strength and RMS delay spread predictions are both considered as separate dimensions in the prediction problem, the difficulties of the empirical approach multiply. This problem is aggravated as other information types such as signal fading statistics are added. As the amount of data increases, the attraction of the empirical modeling approach diminishes.

► **Physical Models** — Unlike empirical propagation models, physical models don't use measurement data for predictions but instead rely on physical laws governing the interaction of electromagnetic waves with the physical elements of the propagation environment. Fundamentally, all of these interactions can be derived from Maxwell's equations (see Balanis, References).

To be effective, physical models require detailed descriptions of the elements of propagation environment for their predictions. For this reason, the weakness of

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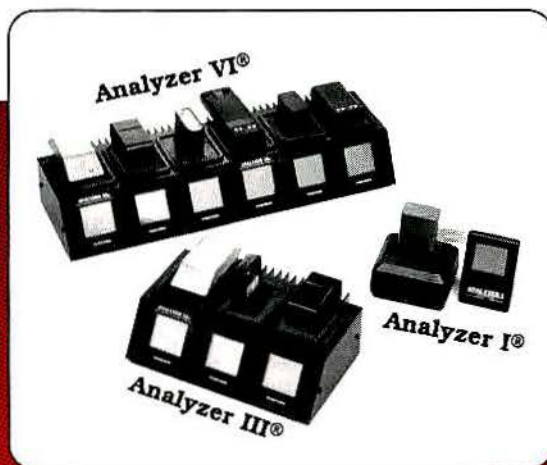
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physical models is that they require extensive databases of information (such as terrain elevations, building wall locations or surface material characteristics) that in turn require significant computer resources to take all this information into account to perform the required propagation calculations. To reduce this problem, simplified descriptions of the propagation environment are usually employed. A typical example is representing an ob-

structing mountain ridge like that shown in Figure 2 as a single isolated "knife-edge." The effect of a single knife-edge on the signal is readily found from classic diffraction theory to provide a field strength prediction at the receiver. The problem is whether a real mountain ridge can be accurately modeled as a knife-edge. Clearly, no mountain ridge is really a knife-edge. Other methods to more accurately represent the mountain ridge

have been used. In each case where a new model of the obstacle was employed, the physical principles governing the effect of the "model" obstacle on the radio waves were known.

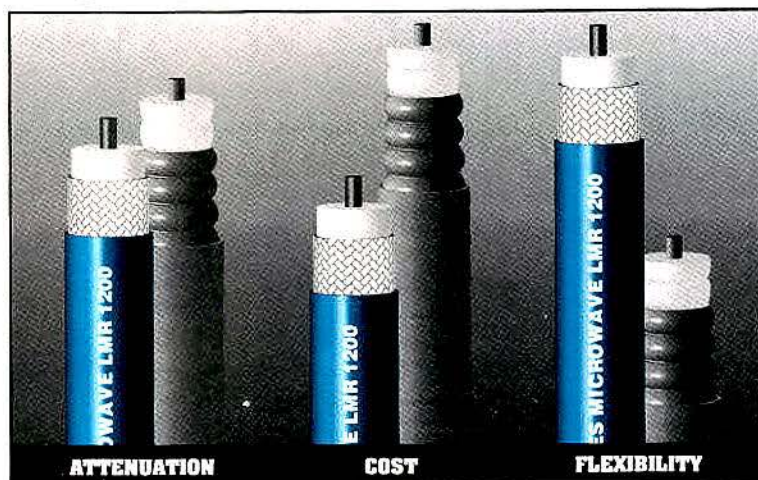
The important aspect of physical propagation models, and their primary distinction from empirical models, is that they attempt to predict the field strength at a precise point in space by considering the specific propagation environment circumstances involved. For this reason, they can be regarded as *site-specific* models. Given a particular transmitter and receiver location, and the propagation environment, a site-specific physical model will provide a tailor-made prediction of the field strength at that point and, as will be shown, other channel response characteristics. Site-specific physical propagation modeling is the approach used here to explore coverage prediction for digital mobile radio systems.

Traditional single path models

Commonly used propagation models attempt to predict the signal strength at the receiver by calculating the path loss for a single radio propagation path from the transmitter via a great circle route to the receiver. Models such as TIREM and Longley-Rice are examples of physical models that predict signal strength using a single propagation path.¹ Even using the assumption that signal energy arrives at the receiver via a single path only, useful results can still be obtained. Figure 3 on page 41 shows a map of predicted received power levels for a five-transmitter system using the TIREM model. With receiver signal power predicted, and knowing the system noise, digital modulation type and data rate, it is straightforward to display maps of bit error rate (BER) as shown in Figure 4 on page 42. By taking into account relative propagation path length delays from various transmitters, and their relative signal strengths, maps of simulcast delay spread can also be readily created as shown in Figure 5 on page 46. Such maps are especially useful for digital paging systems where time delay and frequency offsets can be assigned to each transmitter to re-locate and control the interference areas. Prediction tools, such as EDX SignalPro software, that provide this capability, allow the system designer to quickly evaluate many different offset configurations from a notebook or desktop computer without

¹Strictly speaking, TIREM and Longley-Rice are not pure physical models, since measurement results have been used to establish certain parameters in each model.

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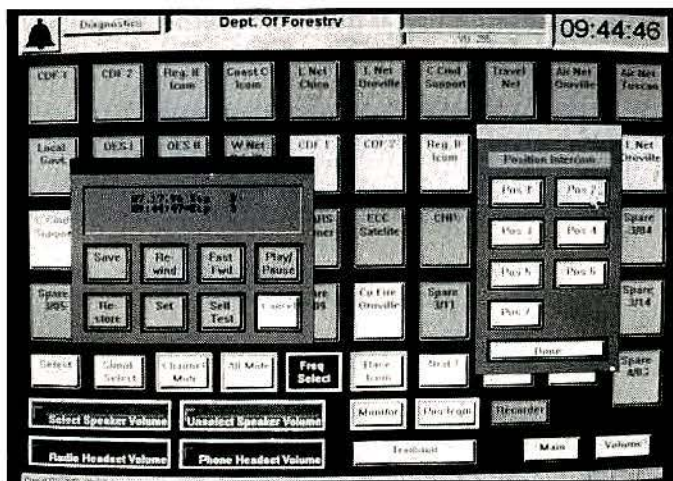
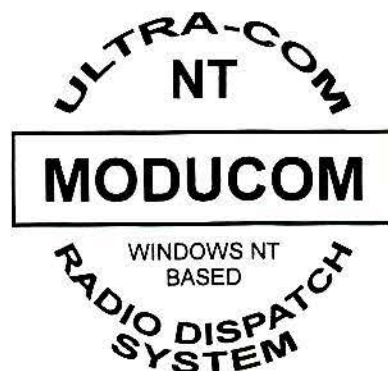
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making time-consuming and expensive field measurements to interactively assess and adjust these parameters.

Although single path prediction methods are a useful starting point, for modern digital systems the answers can sometimes be inadequate or even misleading as will be shown in the concluding part of this article series.

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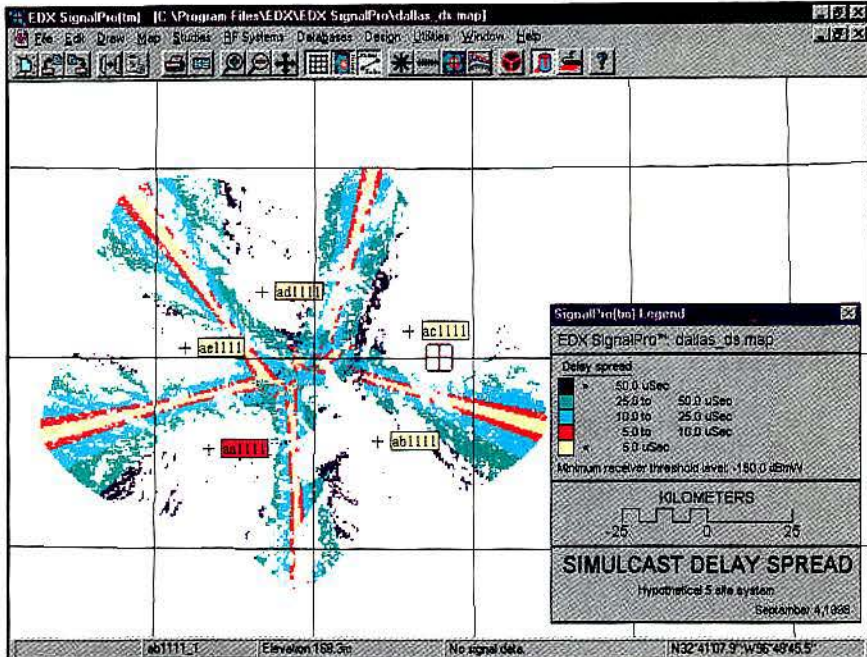


Figure 5. Simulcast delay spread prediction.

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VHF and UHF propagation curves for the fre-

quency range 30 MHz and 1000 MHz. ITU-R, Recommendation 370-6, 1994 PN Series Volume, Propagation in Non-Ionizing Media, 1994.

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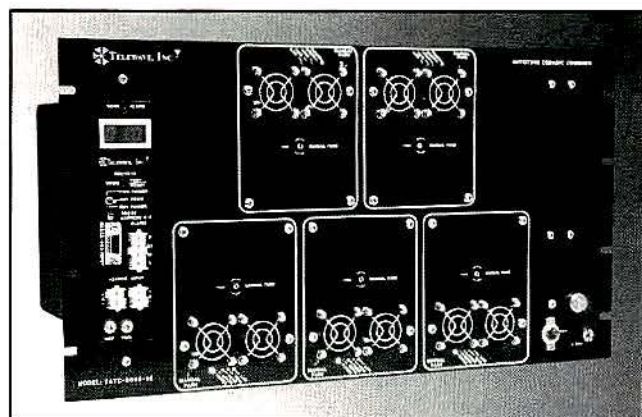
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TATC-8645-1E

Telewave Auto Tune Ceramic-Enhanced Combiners cover the 849-869 MHz SMR band in 5-channel groups, with up to 100 watts power handling and high-speed tuning. Multiple trunking frequencies can now be easily accommodated with real-time response.



ANTTPD44

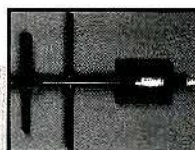
Telewave Antenna Power Dividers are unique in the industry! Frequency ranges from 30-2000 MHz, 500 watt power handling, and nearly zero loss. 2, 3, and 4-way splits available, with TXYLAN™ coating and all brass construction.



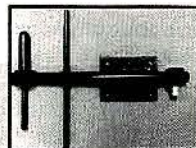
ANTTPD21

Telewave Yagi Antennas now cover 138-2000 MHz and feature 3 different cable attachment and mounting options, as well as fully welded construction and exclusive TXYLAN™ coating.

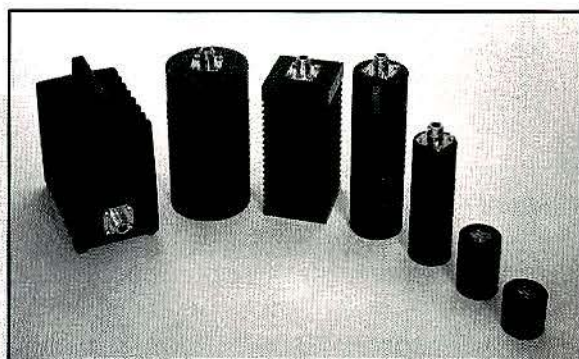
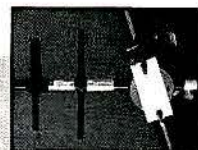
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(continued from page 8)

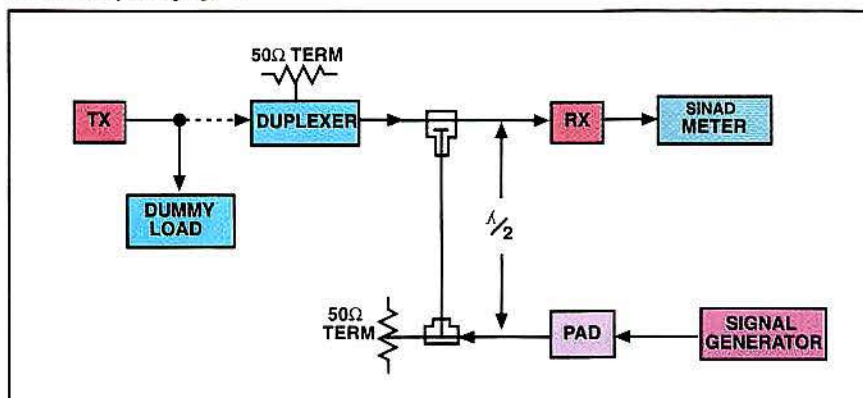


Figure 3. Here a 50Ω termination is placed on the antenna port of the duplexer in order to get a reference benchmark for determining the degradation caused by site noise. See text.

Next, we want to know how much insertion loss the receiver side of the duplexer is causing. Use the setup in Figure 2 on page 8 to determine the amount of insertion loss in the receiver leg of the duplexer. Adjust the signal generator to produce 12dB SINAD again at the receiver output. Let's call this reference level #2. Subtract reference level #2 from reference level #1 to get the duplexer insertion loss. Suppose that reference level #2 is

-117dBm. Subtracting this from reference level #1 (-119dBm) yields

$$-119 - (-117) = -2\text{dB}$$

This is the insertion loss of the duplexer in the receiver leg. Make certain that the transmitter is either not activated during this test or that the transmitter output is directed into a dummy load.

The next piece of information needed

is the effective site sensitivity of the receiver. The setup is shown in Figure 3 at the left, where the antenna is replaced with a 50V dummy load. The signal generator is adjusted to produce 12dB SINAD at the receiver output and the signal generator level is noted as reference #3. Next, in Figure 4 on page 50, the antenna is connected, and the signal generator is re-adjusted to produce 12dB SINAD at the receiver output. The level is noted as reference level #4, and the difference between reference levels #3 and #4 is the site noise degradation of the receiver sensitivity. (Again, the transmitter is disabled for this test.)

Finally, the transmitter is reconnected or enabled, and with the repeater operating normally, set up as shown in Figure 5 on page 50, the signal generator level is again adjusted to produce 12dB SINAD at the receiver output. The level is noted and recorded as reference level #5. The difference between reference levels #5 and #4 is the amount of degradation caused by the transmitter.

If the degradation is several decibels, then the duplexer might need retuning, or there might be a problem with a connection in the antenna line or antenna that is

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Circle (38) on Fast Fact Card

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e-mail: 72731.1235@compuserve.com

Circle (39) on Fast Fact Card

Expect Change

Only Zetron's Series 4000 Communications Control System offers the flexibility to smoothly and economically adapt to your ever-changing dispatch environment.



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Consoles Need more operators? Add one or several desktop, rackmount or video operating positions to your Zetron common control equipment. Mix or match them to best suit your dispatch needs -- they're all functionally interchangeable.

Keys Take advantage of "any button, any function" field programmability. Add or change frequencies, control functions, page stacks, alerts, priority tones, transmit groups, or auxiliary I/O. You can easily customize your console's operator interface to meet the unique requirements of your dispatch center.

Capacity Planning on adding more base or control stations? Expand your Series 4000 up to 24 radio or telephone channels. Additional dual channel cards can be easily installed and configured in the field.

Control Migrating to a trunked radio system? The Series 4000 product family includes interfaces for several popular protocols as well as common standards such as tone remote, DC, local, and E&M. Plus, if you need to control or monitor external devices from your dispatch console, the Series 4000 is the right choice. Whether it's video cameras, doors, lights, alarms, or backup power supplies, the 4000 has auxiliary I/O capacity to handle it all.

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Circle (37) on Fast Fact Card

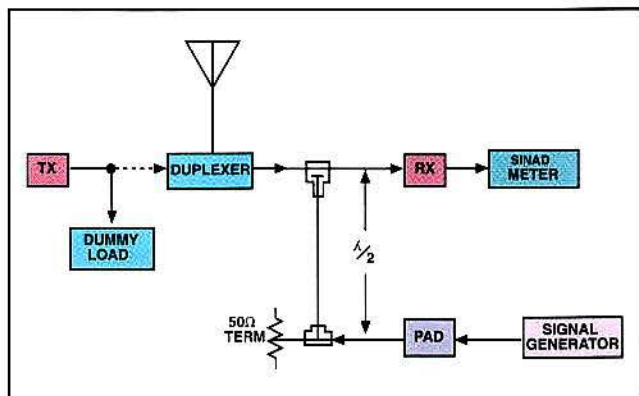


Figure 4. Here, the antenna is reconnected to get a comparison for determining the site noise degradation.

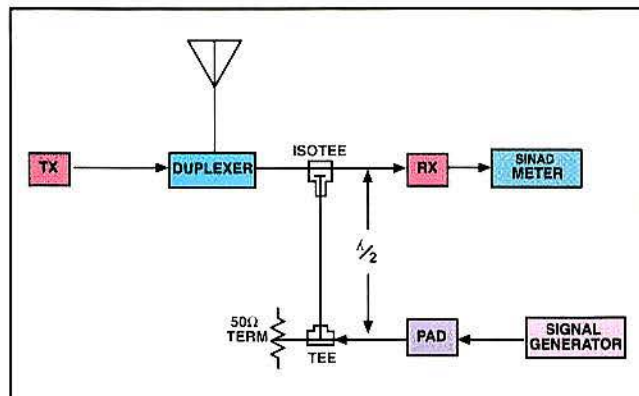


Figure 5. Both the transmitter and the antenna are connected to the duplexer to determine receiver degradation in the full duplex operating mode.

creating excessive noise that is transferred back into the receiver input.

Effective net system sensitivity

The bottom line to all of this is the effective "net" system sensitivity—that is, the system sensitivity in the fully operational mode. The effective net system sensitivity takes into account many factors including site noise, transmitter noise, receiver desense, duplexer tuning and antenna/connector noise. Since the transmit-

ter and receiver must operate at the same time (duplex) then the only way to truly test the "system" sensitivity is in the full duplex mode. The table at the right is a sample of the calculations involved.

It is important to note here that the attenuation of the signal generator padding must be taken into account in the measurements. It is also important to note that the cable connecting the isotee and the straight tee connectors should be half-wavelength ($\lambda/2$). If quarter-wavelength

REF. LEVEL	DESCRIPTION	FIGURE
#1	Bench sensitivity	-119dBm
#2 - #1	Duplex. ins. loss	+2dB
#4 - #3	Site noise degrad.	+3dB
#5 - #4	TX noise degrad.	+4dB
Net system sensitivity		-110dBm

($\lambda/4$) cable were to be used, the open circuit at the isotee might be reflected back to the regular tee as a short circuit.

Until next time — stay tuned!

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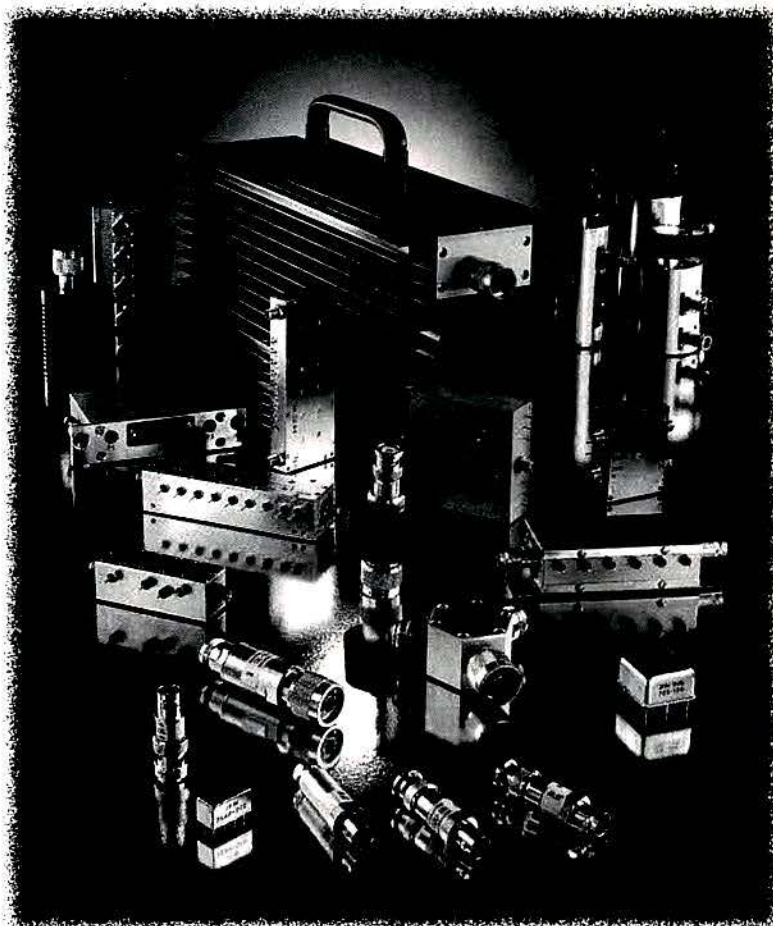
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JFW Industries, Inc.

5134 Commerce Square Drive
Indianapolis, Indiana 46237

Tele. (317) 887-1340 Fax (317) 881-6790



Circle (40) on Fast Fact Card

Product/services showcase



Desktop power supplies

Sleek, low-profile desktop power supplies from **DuraComm** measure 1 3/4" H x 7" W x 7 7/16" D with no top-vent louvers. All models weigh less than 3 pounds. The units are available with 10A, 14A, 18A and 25A, pre-set 13.8Vdc. The units are 80% efficient. Features include MOV full-input ac line protection; ac/dc line filtering.

Circle (301) on Fast Fact Card



Repeater panel

The new TP-163 from **Connect Systems** is the only shared repeater panel available with 112 DCS codes, 51 CTCSS tones, two RS-232 ports and software permitting either online or offline programming.

Call CSI at 800-545-1349.

Circle (302) on Fast Fact Card

Air-dielectric radiating cables



Trilogy Communications offers RMC² radiating cables for RF-restricted areas (buildings, subways, tunnels, etc.). Product features include the only hermetically sealed low-loss air-dielectric cables available, no pressurization required, no soldering for connectorization and RMC² costs far less than corrugated copper cables. Available in 50Ω and 75Ω.

Circle (303) on Fast Fact Card

Multichannel remotes



The Alpha series remotes from **CPI Communications** display the channel/system

number, as well as allow the user to tag them with a 10-character name. Remote systems are available for the various radios from the following manufacturers: Motorola, Kenwood, Radios, E.F. Johnson and Midland.

Call 800-869-9128 for more information.

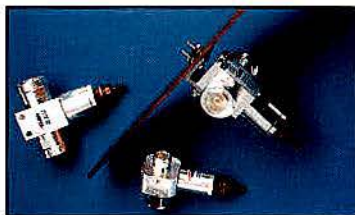
Circle (304) on Fast Fact Card



Decoder

The DC440 from **Optoelectronics** decodes and displays 50 CTCSS tones, 106 DCS codes and 16 DTMF characters. The unit displays DTMF characters at the same time as CTCSS or DCS on a two-line LCD. A serial data jack permits connection to a PC for remote control and data logging. NiCd batteries are available for mobile operations. 2"H x 5"W x 4"D.

Circle (305) on Fast Fact Card



Surge arrester

The new ArrestorPlus T-Series surge arrester from **Andrew** provides multi-strike lightning protection and outstanding RF performance in a compact design that is ideal for confined applications indoors or out. The T-shaped unit features low intermodulation and excellent VSWR. It is available with Type N or 7/16 DIN interfaces.

Circle (306) on Fast Fact Card



Trunking logic controller

New LTR trunking controllers from **Trident Micro Systems** make the move to UHF trunking easy. The Raider is a full-featured dispatch trunking controller with CTCSS/DCS, CWID and repeater disable. The Marauder (shown) uses a high-performance telephone interconnect with two- or four-wire compatibility, audio companding, dial-click decode and encode and ID-specific access levels.

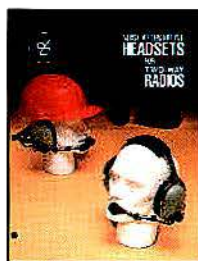
Circle (307) on Fast Fact Card



Ultra-compact portable

The **Vertex VX-10** portable transceiver is available in both VHF and UHF versions. Both feature 5W of power, and each is available in a 102-channel, 16-key version or a 40-channel, two-key version. Despite the small size, the VX-10 is commercial grade—designed to withstand rugged use and abuse typical in public safety, light industrial and business. The radio has been tested to applicable MIL-STD 810 C/D/E parameters.

Circle (308) on Fast Fact Card



Noise-attenuating headsets

A brochure from **David Clark Company** provides information and specifications for the complete line of noise-attenuating headsets, radio adapters and accessories for two-way radios, including the series 6000 headset with noise-canceling mic and adapter cords.

David Clark
Worcester, MA
508-751-5800; E-mail dcci@tiac.net

Circle (309) on Fast Fact Card

Product/services showcase



1996B Buyers' Guide

Tessco's 1996B Buyers' Guide features seven sections covering infrastructure products, mobile and portable accessories, antennas, bench equipment and test and maintenance gear—with complete specs and guaranteed pricing. It lists almost 15,000 products from 240 manufacturers. It's available on a complimentary basis to qualified service organizations by calling 800-472-7373, faxing 410-472-7575 or by visiting their web site at <http://www.tessco.com>.

Circle (310) on Fast Fact Card



Uplink-only repeater

To eliminate noise and dropped calls resulting from interference with transmitted RF from a portable cellular phone inside an automobile, **Antenna Specialists** offers ActiveLink LE, an uplink-only repeater for mobile subscribers. This repeater works an external mobile cellular antenna for enhanced coverage and optimum performance.

Circle (311) on Fast Fact Card



RF power amplifier

Designed for use in conjunction with 900MHz radio modems, this half-duplex modem-compatible RF power amplifier from **VoCom** features TX/RX switching times of 25µS or better, as much as 25W output with as little as 200mW input, 13.8Vdc operation and adjustable output power to maximize efficiency.

Circle (312) on Fast Fact Card



Lightning block protector

The Micro Lightning Block Protector from **PolyPhaser** was engineered as a single broadband device for 980MHz to 2.6GHz, meeting the customer's needs in the PCS and other microwave markets. It exhibits one of the industry's best RF and surge performance in a fully weatherproof, small footprint.

Circle (313) on Fast Fact Card



Coaxial cable

Cell Reach is a new line of high-performance, low-loss, 50-ohm coaxial cables designed for wireless transmission systems. The cables from **CommScope** combine a smooth-wall copper outer conductor and a high-strength closed micro-cell foam dielectric. The cable is triple-bonded, which provides electrical and mechanical stability and low VSWR, and eliminates water migration.

Circle (314) on Fast Fact Card



Keychain pager

The ELITE Keychain pager from **Global Access Pagers**, a subsidiary of Leavitt Communications, is 30% smaller and 50% lighter than most pagers. Featuring 18-message capacity, time stamp with date and alarm, the pager can also display "account due" and can be deactivated over-the-air.

Circle (315) on Fast Fact Card

Analog service monitor



When **IFR Systems** combined the ease of an analog service monitor with the advanced features found in digital instruments, the result was the FM/AM-1200 Super-S. With its impressive standard features, the Super-S earned a dedicated following among technicians installing and maintaining trunking, paging and land mobile systems.

Circle (316) on Fast Fact Card

System design tools



EDX Engineering provides comprehensive design tools for PCS,

cellular and other wireless communication systems. They use the most advanced propagation models to perform coverage, interference and detailed link analysis studies. System planning maps can be plotted along with other descriptive data. DOS, Windows 95 and NT versions are available.

Circle (317) on Fast Fact Card

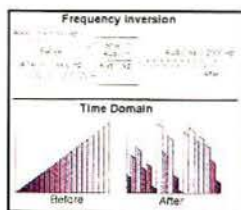


Coaxial connectors

Huber+Suhner's Quick-Fit Type N, 7/16 and 4.1/9.5 connectors for use on foam corrugated copper cables are compatible with all manufacturers' popular cables from 1/2" to 1 5/8". Consisting of only two parts, cable preparation and termination requires no soldering and is achieved in four simple steps.

Circle (318) on Fast Fact Card

Scrambling for two-way



Today the level of security required in the two-way industry simply boils

down to—What can you afford to lose if your conversations are heard by others? **Selectone** offers clear choices to your questions with time and frequency domain scrambling.

800-227-0376
www.selectone.com

Circle (319) on Fast Fact Card



Grounding kits

The SureGround self-securing ground strap from **Andrew** eliminates the need for strap attachment tools and provides protection against lightning strikes as high as 125kA. A tensioned copper clip-on grounding strap ensures proper contact pressure between the strap and the outer conductor and prevents damage from over-tightening.

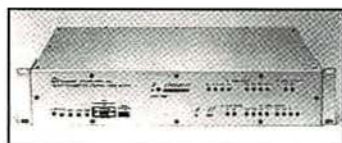
Circle (320) on Fast Fact Card



SCADA, telemetry systems

Economical, easy-to-use, ULTRAc wireless SCADA and telemetry systems from **Zetron** feature PC-based centrals; use of existing radio systems; NEMA cases with battery backup; PLC monitor and control systems; PLC communication via MODBUS; and voice and paging alarms over phone or radio via SentiVoice and SentiDial product lines.

Circle (321) on Fast Fact Card



Transmitter steering controller

The TSAM-1 transmitter steering controller from **CTI Products** works with existing comparators and receiver voting electors to steer eight transmitters. It includes fully programmable control tone generation and CTI Products' exclusive Smart-Steer algorithm. It is expandable to 64 transmitters.

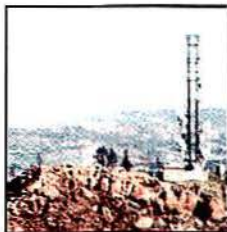
513-595-5900

Circle (322) on Fast Fact Card

Site management

Meridian Communications has

been providing tower space and site management at its many strategically located antenna sites in California for 40 years. Their well-equipped high- and low-elevation multi-user antenna site facilities stretch from the Mexican border to Santa Maria. Meridian continually acquires, develops and enhances its facilities for all types of uses. Call 800-400-SITE.



Circle (323) on Fast Fact Card



CTCSS/burst encoder

The TE-64D displays CTCSS/Burst tones from 67.0Hz to 203.5Hz at 0.1Hz accuracy on a four-digit LED display and operates on 6Vdc-16Vdc. The unit from **Communications Specialists** is ideal for mobiles, nighttime operation or when high visibility is needed.

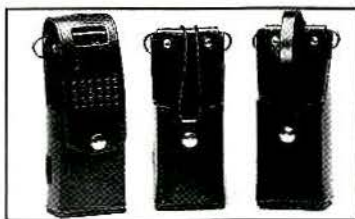
Circle (324) on Fast Fact Card



Battery Analyzer

Cadex's C7000 programmable battery analyzer simultaneously services NiCd, NiMH and SLA batteries. More than 800 configured adapters are available for batteries for portable radios, cellular phones, laptops and camcorders.

Circle (325) on Fast Fact Card



Carrying cases

Leathersmith offers more than 400 models of cases (the most popular models in stock) in a variety of material, including leather, nylon and Dura-hide. Several back-style options, such as Motorola-compatible and G.E.-compatible swivels, are available. Free logo imprinting is available.

800-233-0440

Circle (326) on Fast Fact Card



Jumper Assemblies

Cablewave Systems offers premium low VSWR jumper cable assemblies. Flexwell 1/2" low-loss foam and 1/2" Flexwell superflexible jumper assemblies are tested for a maximum VSWR of 1.2:1 across both cellular and PCS bands. These are stocked in most popular lengths and connector configurations. Cablewave also manufactures RF and microwave products including air-dielectric cables and radiating cables, high-performance connectors, installation accessories, microwave antennas and elliptical waveguides.

Circle (327) on Fast Fact Card

Product/services showcase



King Communications' new Scepter line of VHF, UHF, 800MHz and 900MHz base stations and repeaters feature separate TX/RX modules, 100-channel synthesized operation, 12.5kHz and 25kHz channel spacing, 25W-150W RF power output, CTCSS and DCS and 100% duty cycle operation. The Scepter line offers flexibility for stand-alone use or for integration into multi-channel trunking operations. Models include desktop and cabinet-mount base stations and repeaters, plus a POCSAG digital paging transmitter. All models can be integrated with King Sentor.

Circle (328) on Fast Fact Card



Tracking receiver

The Duet from **Berkeley Vari-ronics Systems** is a portable, 10W transmitter and companion tracking receiver system that is used to characterize PCS propagation with user-selectable chip rates from 10Mbps to 128kbps and will verify actual BER performance, signal strength and time dispersion (multipaths).

Circle (329) on Fast Fact Card



Digital scrambler

The SC20-500 Phoenix scrambler from **Transcrypt International** uses DSP technology to provide next-generation digitally scrambled audio. Ideal for security-conscious public safety agencies, business and industry, and international government agencies.

Call 800-228-0226.

Circle (330) on Fast Fact Card



Pager/radio repair kit

The new 8100-1097 SMD repair kit from **A.P.E. South** contains materials for repairing Motorola pager and cellular products, including tweezers, probes, wetting solutions and solder remover.

305-451-4722; Fax 305-451-3374

Circle (331) on Fast Fact Card



Heavy-duty paging antenna

The HD9-92040 9dBd omnidirectional paging antenna from **Hustler** features a solid mechanical design and a 2" fiberglass radome rated for 150mph winds. The 920MHz-940MHz antenna offers outstanding fringe area performance and is dc-grounded for lightning protection.

Circle (332) on Fast Fact Card



Superflexible cable

With the flexibility of 1/2" superflexible cable and loss comparable to standard 1/2" corrugated copper cable, LMR-600 from **Times Microwave** works well for short feeder and jumper applications. It has a black UV-protected polyethylene jacket for weather protection. The bonded aluminum outer conductor is sealed to the dielectric for further protection.

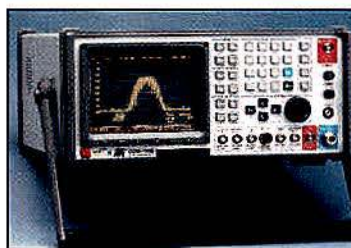
Circle (333) on Fast Fact Card



Low-loss combiners

Telewave introduces two 14-channel low-loss combiners, covering 350MHz and 760MHz. One of the first applications for these high-power multi-channel units is in wireless local loop systems for rural areas and developing countries. Each unit is 19" x 72" and includes isolators and receiver multicouplers. Call 800-331-3396 or visit <http://www.telewaveinc.com>

Circle (334) on Fast Fact Card



Wireless communications service monitor

Hutton Communications is an authorized stocking distributor for IFR. The COM 120B is an advanced wireless communications service monitor providing lightning-fast operation. 800-442-3811; fax 972-239-5264

Circle (335) on Fast Fact Card



Preset dc power supply

The model PPS-4A from **Astron** allows the user to preset the voltage and current without actually loading the unit. The supply is completely solid-state and suitable for bench or rack-mount operation. The unit delivers 0V-16V at 0A-4A and can be adjusted continuously throughout the output range.

Circle (336) on Fast Fact Card

Licensed paging carrier



With more than 40 years of combined experience, **Super Wireless Warehouse** is dedicated to giving its customers the best communications products and service. Thoroughly trained technicians offer full technical support before and after the sale. A huge inventory of new and used pagers, parts, crystals, housings, batteries and same-day shipping are available, as well as such services as Caller ID, prepaid cellular and cellular refurbishing. Unwanted pagers can be put toward a new or refurbished pager.

Circle (337) on Fast Fact Card

Log periodic antenna



Log periodic antennas from **Cel-wave** are designed to provide dramatic reductions in co-channel interference for ESMR, cellular and PCS operators.

The Maximizer antennas offer 45dB front-to-back ratio. Additional features include upper lobe suppression, which reduces interference during mechanical downtilting, and heavy null fill for effective close-in coverage. CELlite technology eliminates rivets, cables and soldered joints. Call 800-CELWAVE for more information.

Circle (338) on Fast Fact Card



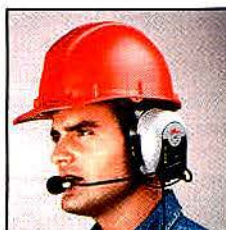
Emergency medical radio

The new Midland Emergency Medical Services (MEMS) radio from **Midland USA**, is a compact, frequency-synthesized programmable FM two-way mobile for medical emergency applications. Available in 30W-90W output power for UHF, it offers as many as 320 channels, programmable in 16 groups. Operators use a UHF hand-held radio with a DTMF keypad to select channels and talk through the mobile radio.

816-241-6400, ext. 1690
Fax 816-920-1144

Circle (339) on Fast Fact Card

ProActive headsets



ProActive headsets from **Noise Cancellation Technologies** use active noise cancellation to

electronically neutralize low-frequency sounds—motors, compressors, fans—that interfere with the understanding of speech. Better understanding means reduced risk of accidents due to garbled, misunderstood instructions and warnings. For more information, call 800-278-3526.

Circle (340) on Fast Fact Card



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Circle (54) on Fast Fact Card

News

Uniden forms company to improve customer service, position for future

Uniden, Fort Worth, TX, has restructured its Land Mobile Radio Division, forming an independent global company, Private Radio Communications (PRC) group, which will specialize in research and development, manufacturing and sales of private mobile radio (PMR) and specialized mobile radio (SMR) products. Uniden formed the company to improve customer service through a more centralized organization and to demonstrate its long-term commitment to the land mobile radio industry.

Plans include doubling the number of engineers devoted to the development of PMR and SMR products by the end of

PRC's fiscal year. The company will also expand its sales force in Fort Worth, Sao Paulo, Brazil, and Beijing, as well as establish new offices in Hong Kong, Singapore, Africa and Europe.

In addition to larger sales and engineering forces, PRC's structure will include several new groups: An after-market support group will have specialists on staff for technical expertise, installations and systems engineering and training support; the operations group will focus on procurement, order fulfillment and inventory management; and a marketing group will develop new strategies, including digital migration and licensing.

Manon Engineering appointed TX RX manufacturer representative

TX RX Systems, Angola, NY, has appointed Manon Engineering, Kirkland, WA, as its Northwest manufacturer representative for its line of products, including multicoupler systems, signal booster systems, filters, duplexers, RF system products and associated hardware. Manon's territory includes Alaska, Hawaii, Oregon, Washington, western Idaho and Montana.

M/A-Com signs distribution agreement with Newark Electronics

In a strategy to strengthen its distribution channel, M/A-Com, Lowell, MA, has signed an agreement with Newark Electronics, Chicago, a catalog distributor. M/A-Com will provide wireless products to Newark's distribution centers throughout the world. M/A-Com's wireless products add breadth to Newark's book and make it valuable to a new market.

Name your channel!



The Alpha series MCR remotes allows you to remote control Motorola's Maxtrac, RadiusGM300, Kenwood TK630, TK730, TK830 and Midland's Syn-Tech XTR radios over any two wire voice grade circuit.

The Alpha series remotes provide an LCD readout for channel number, up to 99, and a ten character channel name, channel up and down controls, speaker volume control and intercom capability between parallel remotes and the radio. Each remote also provides controls and LED indicators for PTT, monitor, scan and privacy functions.

Features

- Simple installation - No soldering, cutting or crimping.
- Provides remote channel indication.
- Programmable ten character name per channel.
- Programming done via front panel.
- No special cables or PC required.



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New Jersey utility company rolls out Racotek mobile data system

Public Service Electric & Gas, a New Jersey utility company, is in the final stages of rolling out a mobile data system from Racotek, Minneapolis, to communicate with more than 700 field service workers in its residential, commercial and industrial appliance service business. Units for more than 500 workers are fully operational, making PSE&G the largest user of cellular digital packet data (CDPD) wireless network technology in the United States.

ogy in the United States.

The mobile data system is expected to allow PSE&G to complete two more service calls per technician per day, to improve customer times and to arm service technicians with up-to-date customer information. In addition, paperwork and double-entry of data have been virtually eliminated. Racotek provided enabling communications technologies and related consulting services.

Ritron, Trident agree to co-develop trunking products and systems

Ritron, Carmel, IN, and Trident Micro Systems, Huntington Beach, CA, have agreed to co-develop and jointly market trunking products and systems for domestic and international distribution.

The alliance will integrate Trident's PassPort npNTS advanced trunking proto-

col and LTR expertise with Ritron's family of RF communications products. These new products are projected for an April introduction and will be available as completely integrated systems for first-time construction or as components for existing systems.

Simmonds buys Circuit World in exchange for common stock

Simmonds Capital Limited (SCL), Wiltondale, Ontario, Canada, is selling its SCL Electronics subsidiary to Circuit World (CW) in exchange for CW stock. SCL then will own 60% of CW stock, gaining control of CW and retaining control of SCL Electronics. CW is a Canadian manufacturer of multilayer printed circuits for telecommunications and information processing.

SCL controls Intek Diversified, Los Angeles, which owns Midland USA, a Kansas City, MO-based manufacturer of land mobile radio equipment. A sale of Intek to Securicor Group, Surry, UK, is pending.

Allen Group, NextWave form strategic vendor agreement

The Allen Group, Beachwood, OH, and NextWave Telecom, San Diego, have entered into a long-term strategic vendor relationship under which NextWave and its subsidiaries and affiliates will purchase \$50 million in wireless PCS products and services from Allen and its subsidiaries during the next five years.

The range of products and services include software and engineering services to be used in designing the RF network and its microwave elements, base station antennas and repeaters and boosters that will be used to expand cell site coverage and provide RF coverage in certain hard-to-reach areas.

The Allen Group has agreed to make an equity investment of \$5 million in NextWave and will extend as much as \$50 million in secured financing for products purchased from Allen.

Communications Electronic Specialties changes name

Communications Electronic Specialties (CES), Winter Park, FL, has changed its name to CES Wireless Technologies. According to a company spokesperson, "the new name better reflects the products and systems designed and manufactured by the company, which was founded in 1974."

CES Wireless Technologies just released a series of mobile data, truck-tracking, GPS, status and computer-dispatch software systems to complement the existing range of microphones, telephone interconnects, trunking controllers, ANI and fleet management products.

Racotek completes deployment for Unisys mobile data system

Racotek, Minneapolis, is completing work for the deployment of a mobile data system for Unisys to communicate with more than 2,000 workers in its field service operations in the United States. Data units for more than half of the company's U.S. field service workers are operational, and additional workers worldwide will be added in 1997.

RAM solicited Racotek in December 1995 to substitute for a subcontractor that unexpectedly ceased operations. Racotek assumed the contract obligations and completed required changes and testing to enable the desired worldwide mobile data system. The system will evolve in several directions, including enabling new portable platforms such as Windows 95. Racotek will also support communications enabling software technologies directly for Unisys.



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Industrial strength weenies

By Robert H. Schwaninger Jr.

For decades, the federal government has extolled the virtue of our nation's industrial might. Political advertising (wooing the labor vote) shows video clips of steel-plant blast furnaces spraying sparks, fields of perpetually pumping oil rigs, phalanxes of combines reaping a golden harvest, and manufactured products surging from factories and assembly plants to be carried by truck, plane, ship and pipeline to a waiting world while the Stars and Stripes wave over a Fort McHenry background.

These are the industries that provide jobs, wealth, hard assets and the ability to defend our nation. Together, they give us the quality of life that we all enjoy and form the foundation of our national wealth. Our industrial might is what we protect in trade agreements and treaties, because without our industrial capacity, we become hostages to foreign production and innovation.

The combined wealth of the industrial giants, including the Big Three automakers, the oil companies, the steel companies and agribusiness, is entrenched, formidable and vast. So, with all of the benefits and might of these industrial behemoths, why are they rolling over and playing dead like a pack of overly domesticated dachshunds when it comes to defending private radio?

At the fall meeting in Washington, DC, of the Industrial Telecommunications Association (ITA), speaker Michelle Farquhar, chief of the FCC's Wireless Telecommunications Bureau told a luncheon audience that the future of industrial radio will consist of two options: private radio users can purchase service from commercial providers—or use unlicensed spectrum. Chief Farquhar was reflecting the newest political agenda of this commission, to eviscerate private radio in favor of commercial providers.

Although the FCC's position is generally repugnant to industrial radio users that depend on the perpetuation of private radio, the attendees at the ITA conference did not voice coordinated resistance to Ms. Farquhar's agenda. In other words, Farquhar got away with her test of the industrial waters without being publicly



stoned for the agency's heresy.

The FCC's plan is to squeeze the spectrum capacity of private radio, through various agency-coordinated methods including frequency allocations, refarming and auctions. Will the FCC kill off private radio? Probably not. Some level of private radio will likely continue, but the ability of private radio licensees to enjoy the fruits of changing and improving technology will be curtailed. Many of these newer technologies require wider bandwidth, not the narrow bandwidth that will be the norm following refarming.

The FCC's plan is not surprising. Commercial providers bid at auction. Private radio users traditionally have not bid because of the geographic-specific nature of private radio uses (manufacturing plants do not stretch across an entire economic area). Given the FCC's often-repeated objective to raise federal revenues through auctions of the radio spectrum whenever and however such auctions might be held, it is clear why the FCC is turning its back on industrial users.

What is surprising, however, is the muted reaction from affected industrial radio users. Where is the courage of conviction that we might have expected? Is it that industrial users just haven't "run the

numbers?" If not, I humbly provide some here for anyone's bean counter who hasn't been keeping up with the eroding rights of industrial users.

Imagine a manufacturing plant that employs 500 line workers, supervised by and through the use of private radio transceivers. We can assume that at least one-fourth of the persons will be equipped with two-way radio devices. That's 125 radios working every day, all day. If we then assume that each radio will be operated for only one-fourth of the time that its user is on the clock, each radio-equipped person will employ two hours (120 minutes) of air time per day. For the entire plant, that's 15,000 minutes per day, or 75,000 minutes per week (assuming only *one* shift).

A check of the rates offered by commercial providers demonstrates that most wireless carriers charge around \$0.25 per minute for air time. Often, there is a discount for the first minutes used. For example, 200 minutes of air time per month, per radio, is free, with additional air time at the twenty-five cents per minute rate. If we apply this formula to our hypothetical factory, the industrial user will pay, following the initial use discount, \$75,000 per month or \$900,000 per year

Schwaninger, MRT's regulatory consultant, is a partner in the law firm of Brown and Schwaninger, Washington, DC. He is a member of the Radio Club of America.

for commercial service. Assuming lower prices through increased competition, the price tag is probably closer to \$400,000.

So, the guy who owns the plant has increased costs of \$400,000 per year, with no corresponding increase in efficiency, output or profit. Instead, the money is loaded onto the fixed cost side of the ledger and must be made up in pricing of the plant's produced goods, which will affect what consumers pay and, perhaps, the size of the plant's work force.

As if that weren't bad enough, the commercial system is usually not designed to accommodate the specialized needs of the industrial users, including the assurance that the transceivers are rated for industrial use. Instead, the industrial user is offered the "vanilla" radios which the commercial provider has determined will be used in association with its system. Therefore, the industrial user may actually lose efficiencies while being forced to pay more for telecommunications capacity.

Although some industrial commenters have pointed out these economic facts to the FCC in some recent proceeding, there is yet to be found a coordinated, financed effort by industrial users to dissuade the FCC from its "auction at all costs" path, with commercial radio being viewed as the panacea for all telecommunication needs. The collective courage of the industrial community simply has not been found. Instead, the industrial giants are acting like political pygmies.

Perhaps the industrial users can take heart in a pledge made by Vice President Al Gore, who said at a Knoxville, TN, fund-raiser in October that the administration will not auction spectrum that is occupied by incumbent licensees. That pledge, if made good, should protect many existing industrial licensee's use of the spectrum. It will not, however, provide future growth and access to newer technologies.

I'm just one loudmouthed lawyer in Washington, DC—the town that attorneys know as having personal jurisdiction over the devil. I don't own a manufacturing plant, run a transportation business or raise thousands of acres of shining wheat. However, even a simple citizen like me can see that the demise of private radio will cost industrial users a huge chunk of money that will not raise our nation's industrial competitiveness a whit. My naive advice to the industrial users, who will be the first victims of the FCC's bias toward commercial operators, is *fight back*. At least you won't keep looking like a bunch of doe-eyed wimps that haven't the courage to complain.




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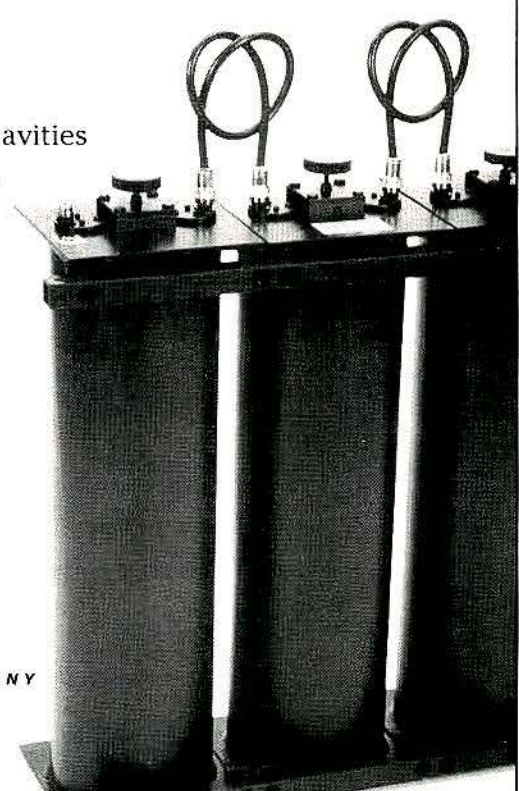
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Key chain pager offers over-the-air churn-control features



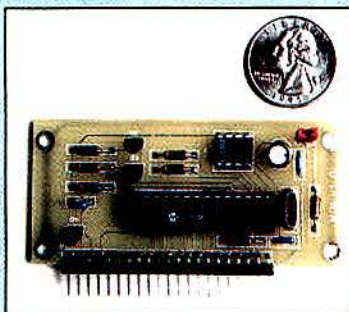
Global Access Pagers' ELite Keychain numeric pager has a removable key chain and holster. Features include three-button operation, 18-message capacity and time stamp. Remote disable and OTA customer account notices are included to reduce churn. Global Access markets the pagers to dealers on an exclusive territory basis.

Circle (401) on Fast Fact Card

Readers' choice

Of all the new products and services in the May 1996 issue, the one reprinted here generated the most reader requests for additional information. If you missed it the first time, here is your opportunity to acquire more information on it. Just circle the corresponding Fast Fact Card number on the card found in the back of this issue and mail the card to us.

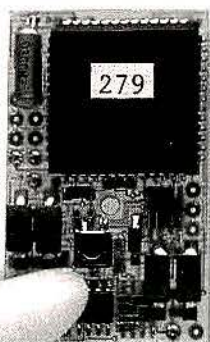
Unit adapts FM transmitter for packet-form GPS data



The MIM module from Clement Engineering is a miniature APRS-compatible packet-radio telemetry unit. When attached to a suitable FM transmitter, the unit can send APRS GPS position reports, analog and binary telemetry in packet form, beacon text messages and a CW Morse ID. The unit accepts GPS data for position reporting and can telemeter five A/D inputs as well as eight bits of parallel digital data.

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Dispatch system includes internal diagnostics, advanced logic devices

The Ultra-Com NT from Modular Communications Systems is a Microsoft Windows NT-based communications dispatch system. Software allows users to control screen appearance and system functions. A diagnostic program performs hardware and software tests and recommends corrective action. The console uses complex programmable logic devices (CPLD) technology to reduce the number of discrete integrated circuits and to provide greater hardware flexibility. The operator position includes an Intel Pentium CPU with 16MB of RAM, a 680MB hard drive, a high-resolution monitor and a digital audio module package. A touch-screen is available as an option.

Circle (402) on Fast Fact Card

Emulator tests multipath fading for TDMA standard



Noise Com has enhanced its MP2500 multipath fading emulator to meet the requirements of TDMA specifications (TIA/EIA-627). The instrument has TDMA-specific test parameters stored in its memory. Having a frequency range of 800MHz to 2.5GHz, and RF bandwidth of 6.0MHz, the MP2500 also tests GSM, DCS 1800, CDMA and PDC digital cellular and PCS standards. The unit emulates wireless communication channels with as many as 12 different reflected signal paths.

Circle (403) on Fast Fact Card

Unidirectional amplifier extends paging coverage



The SelectAmp 1618 series unidirectional amplifier from Andrew gives paging service providers the ability to extend coverage into areas previously shielded from RF penetration. The amplifier is channelized for high selectivity, which enables it to reject any other paging services in the area. The amplifier provides selective channel amplification of frequencies in the 929MHz-932MHz paging band. The unit will also pass as many as four selected frequencies determined by the operator. Features include individual gain adjustment for each channel for continuous control through the 60dB-100dB range, a factory-installed RS-232C interface and software for customized installation and programming.

The unit will also pass as many as four selected frequencies determined by the operator. Features include individual gain adjustment for each channel for continuous control through the 60dB-100dB range, a factory-installed RS-232C interface and software for customized installation and programming.

Circle (404) on Fast Fact Card

Wide-range receiver includes 1,000 memory channels



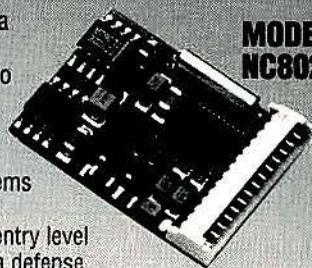
The IC-R8500 all-mode, wideband receiver from Icom America continuously covers a range from 100kHz to 2,000MHz, with 10Hz resolution. Coverage allows signal reception in SSB, CW, AM, AF and WFM modes. IF-shift and audio peak filter (APF) functions are built-in. A noise blanker, an RF attenuator and selectable AGC functions clarify the desired signals. The unit has 1,000 memory channels to store frequency, mode, tuning steps and RF ATT information. The channels are divided into 20 banks of 40, with 100 channels for auto-memory write scan and another 100 channels for skip scan. Scanning speed is adjustable to as many as 40 channels per second, in both memory and programmed scans, with adjustable delay. A RS-232C serial port allows direct computer control and monitoring receiver functions and levels.

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Circle (405) on Fast Fact Card

VOICE SECURITY ENCRYPTION

The Model NC802 is a miniature inversion scrambler designed to provide intermediate level security for two-way radio voice communication systems and is a perfect, cost effective solution to entry level voice scrambling as a defense against unauthorized or casual listeners. The NC802 provides eight user selectable carrier codes commonly used by other manufacturers and interfaces easily to most radios with near transparency to the user.



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NORFAX DOC.# 5755

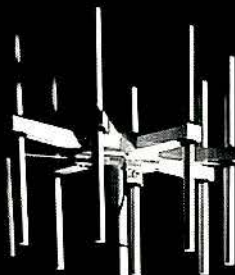
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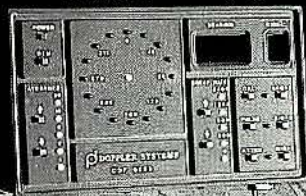


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New products

Right angle 7/16 DIN connector reduces PIM



Times Microwave Systems has added the TC-600-716M-RA 7/16DIN right-angle crimp plug to its line of connectors for LMR-600 cable. The center conductor is captivated to assure proper pin depth. The design includes integral O-ring weather sealing. All portions of the connector in the RF path are silver-plated to minimize passive intermodulation. The matching section of the connector exceeds 1.25:1 VSWR to a level of 2GHz.

Circle (406) on Fast Fact Card

Digital paging test option handles multiple formats

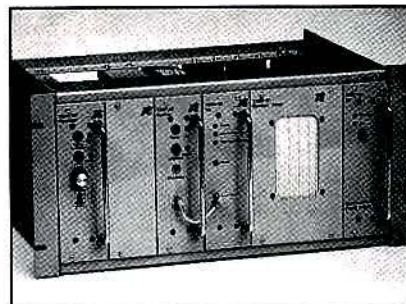
IFR Systems has added the AC510 Paging Encoder to the options for its communications service monitors. The encoder generates analog and digital selective signaling protocols including Flex, NEC D3, POCSAG and Golay. Microprocessor-controlled, the unit features intuitive access of signaling formats, internal memory for the storage and retrieval of custom setups, and simple keypad control of frequency, timing and general-purpose setup parameters. The paging encoder can be directly controlled through selected IFR Systems test sets.

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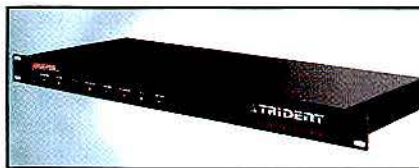
Modular base station-repeaters offer flexibility

The High Sierra line of base station-repeaters from Tait Electronics are high-performance modular systems offering operational flexibility and easy maintenance. Tait T800 series modules can be configured as fixed or portable base stations, in-band or cross-band repeaters, or trunked repeaters, all with a wide choice of output power. Modules can be mounted in freestanding cabinets, in 19" racks or on Slimline panel units. Weatherproof battery-powered portable units are also available. The units can be configured for as many as eight channels (VHF, UHF or 800MHz) externally selectable, local or remote. The modules are PC-programmable for as many as 128 frequencies.

Circle (408) on Fast Fact Card



UHF trunking controllers protect against interference

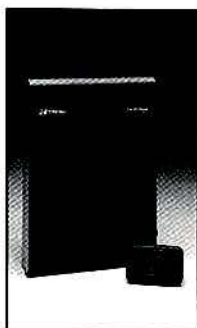


The Raider and Marauder LTR trunking controllers from Trident Micro Systems aid entry to UHF LTR trunking with

built-in CTCSS and DCS, and an exclusive repeater disable device that provides interference protection for co-channel users. The Raider is a full-featured dispatch trunking controller. The Marauder incorporates a high-performance telephone interconnect with two- or four-wire compatibility, audio companding, dial-click decode and encode, and ID-code-specific access levels.

Circle (409) on Fast Fact Card

Paging system tester verifies timely page reception

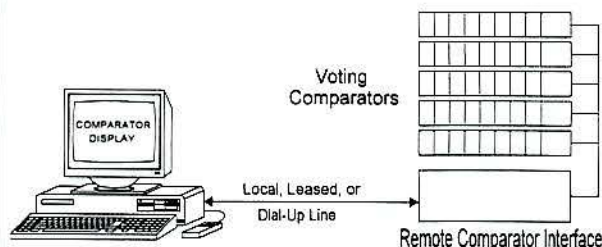


Zetron's model 1515 VeriPage tests an entire paging system from end to end and provides prompt verification of any malfunction. A vibrating pager, of any make, is connected to a VeriPage located inside the coverage area. VeriPage dials a paging terminal at user-defined intervals to activate the pager to which it is connected. The unit detects when the pager receives the signal and resets its interval timer until the next page. If the page is not received within a time limit, VeriPage automatically dials as many as

10 programmed telephone numbers to deliver voice, numeric or alphanumeric messages advising maintenance personnel. Operators can use the same land-line connection to acknowledge alarms and to prevent further notices. DTMF entries can also be sent to open or to close the unit's integrated control relays. Each tester can monitor four paging systems and their associated pagers.

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VHF vehicular repeater extends handheld range



The SVR-200V VHF vehicular repeater provides extended range to VHF handhelds by crossband or in-band repeat operation with an existing mobile. The repeater from **Pyramid Communications** uses

the 150MHz-174MHz range. The unit is Motorola PAC/RT-compatible and includes features for "first man out," priority sampling, multi-vehicle operation and optional remote mobile channel steering via DTMF signaling from the handheld. The repeater is PC-programmable for all operating parameters.

Circle (411) on Fast Fact Card

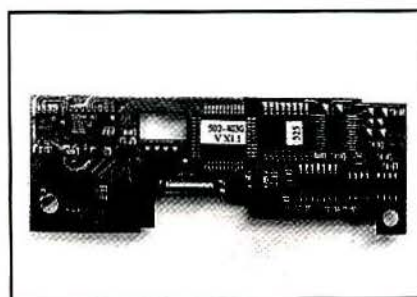
Antennas fight interference with high front-to-back ratio



Celwave has designed the Maximizer log-periodic antennas to reduce co-channel interference experienced by operators of cellular, PCS and ESMR systems. The antenna offers a front-to-back ratio of 45dB and includes upper lobe suppression to reduce interference even during mechanical downtilting. Heavy null fill provides effective close-in coverage. The antennas are constructed with the company's CELite technology to eliminate rivets, cables and soldered joints.

Circle (412) on Fast Fact Card

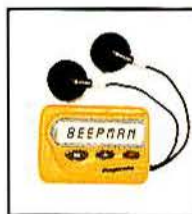
Digital logic boards enable trunking for mobiles



SmarTrunk Systems has released trunking logic boards for both Motorola and Kenwood mobile radios. The ST-868M50 board enables trunking for the Motorola Radius SM50/120. The ST-865KW2 board enables trunking for the Kenwood TK-760/768/860/868 mobiles. Both boards support radio kill for nonpaying users, programmable call-limit timers on a per-user basis and the storage of complete call record accounting information. Other features include store-and-send dialing, automatic 10-number memory speed dial and last-number redial.

Circle (413) on Fast Fact Card

Numeric pager incorporates FM radio tuner



The Beepman from **Pagerola** is a numeric pager combined with an FM radio. The unit comes complete with headphones and digital FM tuner. Paging features include 16-message memory, front-view display, 10 selectable melodies/beep alerts, vibration alert, clock, alarm clock, time stamp, eight on-screen icons and power timer. The pager recognizes four ID codes for receipt of messages and includes memory backup and message protection. The front-view, backlit display can display 21 characters for each message.

Circle (414) on Fast Fact Card

Mobile combines data modem, digital voice

M/A-COM Wireless Systems' dual-band mobile radio combines an advanced data radio modem and a mobile radio in a compact package. The unit supports CDPD in the AMPS cellular band and M/A-COM's 10.2kbps Private Network Protocol as well as 6.0kbps AMBE digital voice in the 800MHz SMR band. The radio is compatible with off-the-shelf TCP/IP protocol stacks. The digital signal processing architecture allows a single radio to be programmed to handle a variety of channel bandwidths, modulation techniques and data protocols. An internal GPS receiver is available as a factory option.

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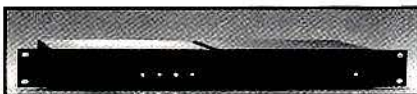
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Circle (44) on Fast Fact Card

New products

Shared repeater tone panel offers on-line programming innovations



Connect Systems (CSI) has added the model TP-163 to its line of shared repeater tone panels. Available in either a single or dual 19" rack-mount configuration, the panel's innovations include on-line or off-line programming using the TP163MGR application program. Features include cross-busy input for LTR overlay and separate DCS and CTCSS level controls. The unit can support 163 users with 51 CTCSS tones and 112 DCS codes, prepaid air time for as many as 163 blocks, and it can track time and hits per user. Other features include CTCSS reverse burst and DCS turn-off code for squelch tail elimination, over-the-air DTMF programming and low standby current. Front- and rear-panel RS-232 ports allow use of a modem and a PC or laptop to perform local or remote programming.

Circle (416) on Fast Fact Card

Corrugated and braided cables resist moisture with clean-stripping bond

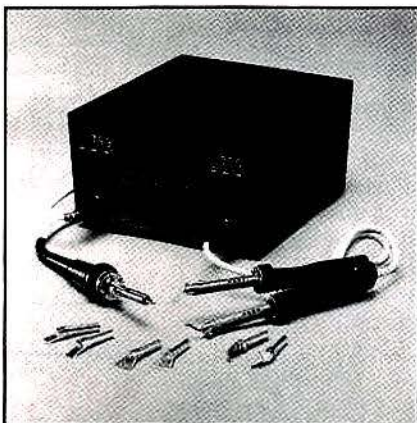
Amphenol has added a line of 50Ω corrugated cables, braided cables and connectors to its line of connection products. The TXL corrugated copper and TWB braided cables are designed to offer greater strength, resistance to water migration and easier connection installation for wireless applications, via a pre-coat process used to bond the clean-stripping center conductor to the foam dielectric. The dielectric is made of a high-compression strength, closed-cell foam. The polyethylene jacket is UV-stabilized



and abrasion resistant. The corrugated TXL cables are available in superflexible 1/4", 3/8" and 1/2" as well as standard 1/2" and 7/8" sizes. Sizes for TWB cables range from RG58 to 1/2" equivalents.

Circle (417) on Fast Fact Card

Digital solder-removal station continuously shows temperature



The EX-755 solder and SMT removal station from Automated Production Equipment is a digital control for critical-temperature soldering on all surface-mount and thru-hole components. Temperature is continuously displayed on an LED readout. The system is designed to avoid thermal shock, unwanted heating and crystallization of adjacent solder joints.

Circle (418) on Fast Fact Card

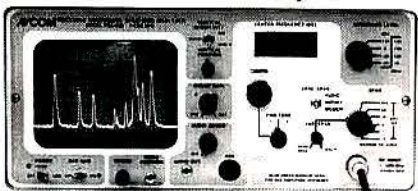
High-speed UHF transmitters offer range of power for paging

Glenayre has added three high-speed UHF paging transmitters to its GL-T8000 series transmitter line. The transmitters offer a power range of 20W-500W and support all existing protocols including high-speed, four-level modulation.

Circle (419) on Fast Fact Card

NEW EXPANDED COVERAGE AVCOM's PSA-65B

Portable Spectrum Analyzer 1-1250 In One Sweep MHz!!



AVCOM's newest Portable Microwave Spectrum Analyzer, model PSA-65B, has an expanded frequency range from less than 1 MHz to 1250 MHz, for the amazing price of \$2930.

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Circle (45) on Fast Fact Card

Distribution

Lindren RF Enclosures, Glendale Heights, IL, selects Olson Technical Sales, Issaquah, WA, as northwest regional sales representative for EMI/RFI shielding systems sold in Northern California, Oregon, Washington and British Columbia.

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IMTA's digest predicts trunked radio growth and opportunities

The 900-page *Global Digest for Commercial Trunked Radio Systems*, published by the **International Mobile Telecommunications Association (IMTA)**, provides comprehensive information regarding the growth of the trunked radio industry worldwide. The result of a year's worth of research, information in the digest was obtained from numerous regulatory agencies and commercial trunked radio operators in a variety of countries. The digest includes comprehensive regulatory and market analyses of 45 countries where the commercial trunked radio industry is active. Free information updates to the digest are available for one year.

Circle (451) on Fast Fact Card

Sourcebook offers information on the satellite industry

The *Satellite Communication Applications Handbook*, from **Artech House**, offers comprehensive information on the exploding industry of satellite communication and pinpoints elements that make satellite applications successful. The handbook shows how to create and effectively apply satellite services in a highly competitive market. Without the use of confusing jargon or heavy mathematics, the handbook expands upon critical technologies such as digital compression of video and voice, on-board satellite processing, VSAT hub architecture and radio positioning.

Circle (452) on Fast Fact Card

Brochure features network analyzers

Anritsu Wiltron's color brochure on its 50000A-series network analyzers discusses such product features as convertible SWR autotesters, relative group delay software (54100A option 8), materials measurements systems, precision return loss (standard on 54100A), compatible synthesizer models and 56100A scalar network analyzer. The 50000A-series analyzers also include ISO-9000 compliance, source harmonic effects, directivity and connector match improvement. The 54100A's relative group software simplifies testing for filters, receivers and frequency.

Circle (453) on Fast Fact Card

Guide explains propagation effects

Artech House's *Introduction to Radio Propagation for Fixed and Mobile Communications* explains the propagation effects mobile communications engineers may encounter when working in fixed-link and mobile radio systems. The book explains how and why propagation occurs, as well as techniques for minimizing transmission degradation and optimizing signal performance. The radio refractive index (RRI), basic system planning techniques, pros and cons of path loss predictions and potential problems of in-building transmission are key topics of the book.

Circle (454) on Fast Fact Card

Sourcebook discusses telecommunications projects

The New Telecommunications Environment: Opportunities for Electric Cooperatives from **The National Rural Electric Cooperative Association (NRECA)** discusses telecommunications projects for electric cooperatives, including SCADA, feeder automation, automatic meter reading, video programming, telephony, cellular and the Internet.

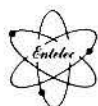
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Siciliano



Pestell



Spedaliere



Fein

Michael Siciliano, sales engineer for Power Conversion Products (PCP), Crystal Lake, IL, advances to south central regional sales manager.

Nigel Pestell departs Motorola's Advanced Messaging Group, Fort Worth, TX, as marketing and product manager to join Castle Tower, Houston, as vice president of international acquisitions and development.

Changes at Allen Telecom Group (ATG), Cleveland:

Gary Spedaliere leaves Midland International, Kansas City, MO, as engineering manager to join ATG as sales engineer.

David Fein leaves MPD, Hauppauge, NY, as manager of international business development to join ATG as director of product management for its Site Management Division.

Robert A. Steuernagel leaves MTA-EMCI, Washington, DC, as vice president to join Authentix Network, Tucson, AZ, as vice president of marketing.

Dennis Andrews leaves XSOF, a business division of Xerox, Palo Alto, CA, as president to join Subscriber Computing (SCI), Irvine, CA, as president. Andrews replaces **Mark Nielsen**, who is now chairman of the board at SCI.

Changes at EDX Engineering, Eugene, OR:

Steve Messick departs Dynamix, a division of Sierra Online, Eugene, as programmer I to join EDX as lead programmer.

Jody Kirtner departs the Israel Transportation Planning & Research Institute, Tel Aviv, Israel, as cartographic analyst to join EDX as geographic information systems (GIS) specialist.

Tony Sellers leaves BellSouth, Atlanta, as corporate planning consultant and the *Atlanta Journal-Constitution* newspaper as senior research analyst to join Mitsubishi Wireless, Braselton, GA, as product planner for the cellular and PCS product lines.

Ken R. Lawler leaves Unipage, DeSoto, TX, as vice president to join Wacom Products, Waco, TX, as sales manager.

Changes at TekNow, Phoenix:

Russ B. Carpenter leaves HiTecSoft, Scottsdale, AZ, as product manager to join TekNow as director of marketing.

Carrie Everett leaves Viasoft, Phoenix, as marketing communications specialist to join TekNow as marketing coordinator.

Kathy Hodge-Woodard leaves Glenayre Electronics, Duluth, GA, as regional sales manager for the mid-Atlantic states to join TekNow as eastern regional sales manager.

Monte Russo leaves Glenayre Electronics as northeastern regional sales manager to join TekNow as western regional sales manager.

Letters from readers

Truck causes radio interference:

I've run into a problem that I need help with, and your readers may also need to know about this problem. My customer has a '93 Chevy six-cylinder pickup truck that is causing interference to the two-way radio receiver on 158.385MHz. It appears that the vehicle's computer is producing a signal every 1MHz from about 40MHz to 200MHz and was found with a spectrum analyzer. The Chevy dealership replaced the computer, and the problem is still there. Another '93 truck was tested and found to have these same signals but at even multiples: 157.000, 158.000, 159.000, etc. An '87 truck was tested, and its signal was at 158.375, 159.375, etc. So far, I'm having a problem getting through to General Motors or Delco for some help. Maybe one of your readers has already run into this and has some help for me? How about running this through your magazine?

Jim Hiatt
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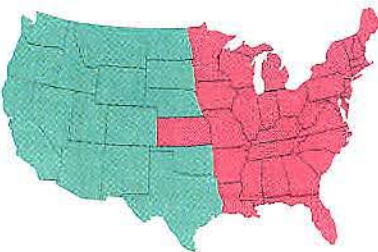


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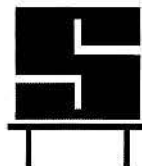
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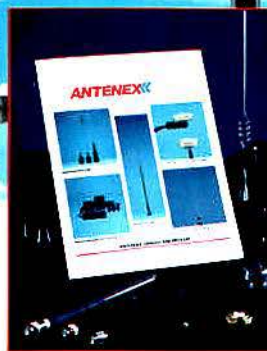
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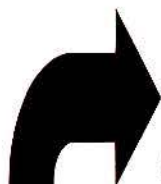
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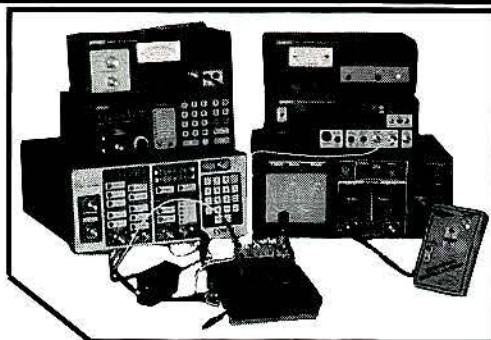
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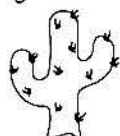


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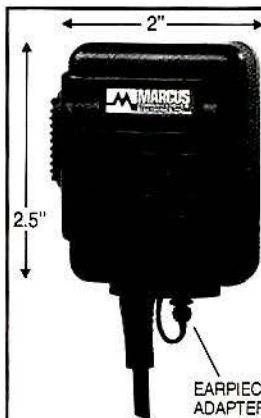
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UHF: 400~512 MHz*

- 5 Full Watt Power Output!!
 - Ultra Compact Size - 2.2"W x 3.9"H x 1.2"D
 - 2 Key, 40-CH (16 Key, 102-CH optional)
 - ARTS™ Auto Range Transpond System™ warns when moving out of range
 - Built-in Voice Encryption (102-CH version only)
 - Built-in DTMF Selective Call
 - Transmit Battery Saver lowers TX power when near base
 - 8-CH Alphanumeric LCD Display
 - Multiple Scan Modes with Priority
 - Manage channels in up to 9 groups
 - Meets new Part 90 FCC Requirement
- For complete specs, features, and details, call for our full-color brochure, today!

Shown with optional 16-Key, 102 CH keypad.

Circle (2) on Fast Fact Card

*This device has not been approved by the Federal Communications Commission. This device is not, and may not be, offered for sale or lease, or sold or leased until the approval of the FCC has been obtained.

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TP-3200 **\$279.95**

Full Featured Shared Repeater Tone Panel with ALL 157 CTCSS/DCS codes. In Desktop or Rack Mount version.



CSI-100 **\$749.95**

Video Modem. Sends and receives broadcast quality, single frame, color video over ANY narrow-band communications channel.



ID-8 **\$69.95**

Automatic Morse Station Identifier. Meets all FCC ID Requirements. Fully field programmable with included keypad. 1.85" x 1.12" x .35"



TE-64 **\$79.95**

Self-contained Encoder, Rotary Dial Selection. Great for the Benchtop. 5.25" x 3.3" x 1.7"



CC-1/CR-1 **\$49.95 each**

Surface Mount Component Kits for repairing SMT circuits. CC-1 for capacitors/CR-1 for resistors.



PE-1000 **\$224.95**

Desktop Paging Encoder. Two-tone sequential, other formats available. 7.5" x 7.8" x 2.7"



PE-2P **\$54.95**

Two-tone Sequential Encoder. Sub-assembly mounts inside radio or other enclosure. Multiple call capability. 1.25" x 2.0" x .4"



SD-1000 **\$59.95**

Two-tone Sequential Decoder. Programmable unit provides switched outputs from two-tone paging calls. 1.25" x 2.0" x .4"



DTD-1 **\$49.95**

Single Function DTMF Decoder. Provides switch outputs via DTMF. 1.25" x 2.0" x .4"



PE-4/PE-15 **\$79.95**

Multiple Call POCSSAG (RPC-1) Paging Encoders. Where direct control of local area paging is desired. 1.78" x 1.03" x .35"



DCS-23 **\$59.95**

Digital Coded Squelch Encoder-Decoder. Programmable to all codes. 1.36" x 1.18" x .25"



TS-32P **\$57.95**

Programmable CTCSS Encoder-Decoder. Tone squelch for any FM transceiver. 1.25" x 2.0" x .4"



TS-64 **\$54.95**

Sub-miniature Programmable CTCSS Encoder-Decoder. 1.7" x .78" x .25"



SS-32SMP **\$27.95**

Sub-miniature CTCSS Encoder. Jumper programmable. .53" x 1.0" x .16"



SS-32PA **\$28.95**

Programmable CTCSS Encoder. Custom tones or audible tones also available. .9" x 1.3" x .4"

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